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ABSTRACT

This volume is composed of 11 source documents which report activities sponsored by the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, deliberations of a subgroup of the National Science Foundation Engineering Advisory Committee, and a paper prepared for the Pfizer Corporation. The first four presentations address the teaching/learning of mathematics, science, and technology in grades K-12. Issues of appropriate content and process are discussed. Suggestions for changing some of the content of traditional elementary and secondary education are presented and arguments for the need for all students to study mathematics, science, and technology every year during their elementary/secondary education are made. Section five reports on the uses of technology as a tool in education rather than learning about technology. The last five sections report on: research and cognition and behavior relevant to education in mathematics, science, and technology; results of a 50-state survey of initiatives in science, mathematics, and computer education; magnet schools; an assessment of programs that facilitate increased access and achievement of females and minorities in K-12 mathematics and science education; a case study of Lyons Township (LaGrange, Illinois) high school computer literacy program; and business' role in precollegiate education. (JN)

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EDUCATING AMERICANS FOR THE 21st CENTURY:

A plan of action for improving mathematics, science and technology education for all American elementary and secondary students so that their achievement is the best in the world by 1995

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THE NATIONAL SCIENCE BOARD COMMISSION ON PRECOLLEGE
EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY

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FOREWORD

This Volume is composed of source documents which report activities sponsored by the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, deliberations of a subgroup of the National Science Foundation Engineering Advisory Committee, and a paper prepared for the Pfizer Corporation. Five of the documents are reports from conferences on mathematics, science and technology education. Participants in these conferences included scientists, mathematicians and engineers, elementary and secondary school teachers and administrators, representatives of professional societies, foundations, private industry and business. Some papers report the results of surveys and assessments of *ad hoc* committee activities.

The first four presentations address the teaching and learning of mathematics, science and technology in grades K–12. Issues of appropriate content and process are discussed. Suggestions for changing some of the content of traditional elementary and secondary education are presented and arguments for the need for all students to study mathematics, science and technology every year during their elementary and secondary education are made.

Emerging new technologies hold promise for more effective education. Though this is addressed in the papers related to subject matter learning and teaching, the topic is sufficiently important to merit a separate presentation on the uses of technology as a tool in education rather than learning about technology.

The new technologies have also allowed new research methods in the areas of cognition and behavior. Some of the findings of this research relevant to precollege mathematics, science and technology education are presented in this volume.

The NSB Commission has seen some excellent programs throughout the country. New initiatives for improving elementary and secondary education, which have been undertaken by states, are described herein as well as model programs and some methods designed to motivate minority and female students to pursue careers in scientific, mathematical and technological fields. And some possibilities for business and industry to become involved in the improvement of elementary and secondary education are described.

The views and opinions expressed in this Volume do not necessarily reflect the views of the NSB Commission, the National Science Board or the National Science Foundation. Nevertheless, in the opinion of the NSB Commission, the contributions provide a useful range of perspectives on ways to improve and continually ensure a sound and effective education in mathematics, science and technology for the youth of our Nation. We hope the ideas expressed in this Volume will aid those actively involved in the improvement of elementary and secondary education and motivate others within their appropriate roles to bring this country's educational system to the forefront in the world by the year 1995.

4

CONTENTS

FOREWORD

1. THE MATHEMATICAL SCIENCES CURRICULUM K–12: WHAT IS STILL FUNDAMENTAL AND WHAT IS NOT

(The Conference Board of the Mathematical Sciences)

EXECUTIVE SUMMARY 1
I. THE NSF/CBMS MEETING 2
II. RECOMMENDATIONS TO THE COMMISSION 3
Introduction 3
Some Additional Recommendations 4
The Working Group Reports 5
— Elementary and Middle School Mathematics 5
— Traditional Secondary School Mathematics 8
— Non-traditional Secondary School Mathematics 11
— The Role of Technology 12
— Relations to Other Disciplines 14
— Teacher Supply, Education, and Re-education 15

APPENDICES:

A. List of Participants 18
B. The Agenda 21
Some Comments on the Agenda 22
C. Listing of Position Papers* by Meeting Participants 23
D. Listing of Position papers* by Non-participants 23

*A limited number available upon request to Commission staff.

2. A REVISED AND INTENSIFIED SCIENCE AND TECHNOLOGY CURRICULUM, GRADES K–12 URGENTLY NEEDED FOR OUR FUTURE

(Conference on Goals for Science and Technology Education Grade K-12)

EXECUTIVE SUMMARY 25
I. Conference Origin and Procedure 27
II. The Crisis in Science and Technology Education 27
III. The Point of View of the Conference 29
IV. Recommendations 34

APPENDICES

Working Group Reports

A. Elementary School Science 38
B. Middle School/Junior High Science 39
C. Biology 40

D. Chemistry 41
E. Physics 42
F. Engineering 43
G. Informal Education for Science and Technology 44
H. K-12 Curriculum 45
I. Integrating Math, Science, Technology 46
J. Technological Tools in Teaching 47
K. Curriculum Development 49
L. Teacher Preparation, Grades K-8 50
M. Teacher Preparation, Grades 6-12 51
N. Support for Implementation and Changes 51
O. Science Education and the Physically Disabled Individual 53
P. List of Participants 54
Q. Agenda 56
R. Bibliography of Papers Reviewed by Participants 57

3. INTEGRATING CONCEPTS OF ENGINEERING AND SCIENCE INTO INSTRUCTION IN GRADE LEVELS K-12

(*Ad Hoc* Subcommittee of the NSF Engineering Advisory Committee)

EXECUTIVE SUMMARY AND CONCLUSIONS 59
INTRODUCTION 60
CURRICULUM CONTENT 62
  Social Studies 62
  Synthesis and Design 63
  Mathematics, Science, and Their Application 63
  Broad Engineering Concepts 63
  Case Studies in Design 64
  Role of the Computer 64
REALITIES OF IMPLEMENTATION 64
  Implication of Recent Attempts at Change 64
  Curriculum Materials and Teacher Development 65
  Importance of the Individual Teacher 66
ROLE OF THE ENGINEERING PROFESSION 67
CONCLUSIONS 67
Attachment I: Membership of the Advisory Committee for Engineering 68

4. FUNDAMENTALS IN PRECOLLEGE TECHNOLOGY EDUCATION

(Junior Engineering Technical Society)

EXECUTIVE SUMMARY 69
1. Introduction 71
2. Questions Raised at the Workshop 72
3. Background 72
4. Definition of Terms 73
5. Technology at the Precollege Level 74
6. Recommendations: 75
  A. Curriculum Revisions 75
  B. Support Systems 77
  C. Treatment of Teachers 79
  D. Approach to Technology in the Schools 80
    1. Elementary School 80
    2. Middle School 80
    3. Secondary School 81
  E. Career Education 82
  F. Computer Use in Learning Environment 82
7. Conclusion 83

APPENDICES:

A. Agenda for the Workshop 85
B. Directory of Participants 87
C. IEEE Response to Crisis in Precollege Science, Mathematics, and Technology Education 89
D. Description of JETS 89

5. REPORT ON EDUCATIONAL TECHNOLOGY

(Conference on the Uses of Technology in Education)

EXECUTIVE SUMMARY 91
I. INTRODUCTION 94

II. EDUCATIONAL TECHNOLOGY—DEFINITION AND DOMAIN

  A. Definition 95
  B. The Computer 96
  C. Educational Television 99
  E. Videotex/Databases/Computer-based Telecommunication 100
  F. Videodisc Systems 102
  G. Intelligent Videodisc Systems 102
  H. Robotics 103
  I. CONCLUSION 103
APPENDIX A
Attendees 105

6. RESEARCH ON COGNITION AND BEHAVIOR RELEVANT TO EDUCATION IN MATHEMATICS, SCIENCE AND TECHNOLOGY

(The Federation of Behavioral, Psychological and Cognitive Sciences)

SUMMARY 107
FORWARD 110
I. INTRODUCTION 111
  I.A. Some Problems of Education 113
  I.B. Introductory Examples 115
II. FINDINGS OF RECENT RESEARCH 121
  II.A. The Content of Education 121
  II.B. Participation and Effectiveness 127
III. RESEARCH NEEDS AND OPPORTUNITIES 132
  III.A. Questions of Educational Content 132
  III.B. Participation and Effectiveness 136
IV. STRUCTURES FOR APPLICATION AND SUPPORT 139

7. RESULTS OF A 50-STATE SURVEY OF INITIATIVES IN SCIENCE, MATHEMATICS AND COMPUTER EDUCATION

(The Education Commission of the States)

INTRODUCTION 141
I. Task Forces or Commissions (Quality or Excellence) 142
II. Task Forces or Commissions (Computer Education) 156
III. Graduation Requirements 160
IV. Curriculum Guides and Performance Standards 166
V. Science and Mathematics Programs 170
VI. Computer Education Programs 173
VII. Summer Institutes, Magnet and Residential Schools 181
VIII. Recognition and Awards 185
IX. Regional Centers 187
X. Teacher Training and Retraining 188
APPENDIX A: STATE CONTACT PERSONS 199
APPENDIX B: ADDITIONAL ECS 50-STATE SURVEYS 203

8. MAGNET SCHOOLS

(Commissioned by the Pfizer Corporation)

ABSTRACT 205
INTRODUCTION 206
Early Magnet Schools 208
The New World Grammar School 211
Contemporary Magnet Schools 212
The Evidence 214
The Future 216
CONCLUSION 220
APPENDIX 224

9. AN ASSESSMENT OF PROGRAMS THAT FACILITATE INCREASED ACCESS AND ACHIEVEMENT OF FEMALES AND MINORITIES IN K-12 MATHEMATICS AND SCIENCE EDUCATION (Summary) 225

(Office of Opportunities in Science, American Association for the Advancement of Science)

10. A CASE STUDY OF LYONS TOWNSHIP HIGH SCHOOL (Summary)

Lorraine Borman and Peter Lykos

PREFACE 229
EXECUTIVE SUMMARY 230
Profile of Lyons Township High School 234
History of Instructional Computing 235
Organization and Management of Academic Computing 236
Student Access to Computing 236
Costs and Budgeting 237
Computer Literacy 238
Computer Science 238
Outreach 239
Lessons Learned 239
Plans and Goals 240
Contacts 240
References 241

11. BUSINESS' ROLE IN PRECOLLEGIATE EDUCATION

(The Conference Board, Inc.)

INTRODUCTION 243
The Educational Qualifications of Newly Hired High School Graduates 244
The Impact of Education Shortfalls on Business Operations 245
Improved Teaching of Mathematics, Science and Technical Subjects 246
Relationships with Mathematics and Science Faculties 246
Exacerbating the Teacher Shortage Situation 247
What Has Business Done to Help? 247
Business Plots Future Actions 249
Top Management's View 249
A Collection of Comments From Respondents 250

I

THE MATHEMATICAL SCIENCES CURRICULUM K-12: WHAT IS STILL FUNDAMENTAL AND WHAT IS NOT

Report from The Conference Board of the Mathematical Sciences
Prepared by Henry O. Pollak, *Bell Laboratories*

EXECUTIVE SUMMARY

Our charge from the NSB Commission was to identify what parts of mathematics must be considered fundamental for education in the primary and secondary schools. We concluded that the widespread availability of calculators and computers and the increasing reliance of our economy on information processing and transfer are significantly changing the ways in which mathematics is used in our society. To meet these changes we must alter the K-12 curriculum by increasing emphases on topics which are fundamental for these new modes of thought.

This report contains our recommendations on needed changes—additions, deletions, and increased or decreased emphases—in the elementary and middle school mathematics curricula and a statement of more general concerns about the secondary school mathematics curriculum.

With regard to elementary and middle school mathematics, in summary, we recommend:

- That calculators and computers be introduced into the mathematics classroom at the earliest grade practicable. Calculators and computers should be utilized to enhance the understanding of arithmetic and geometry as well as the learning of problem-solving.
- That substantially *more* emphasis be placed on the development of skills in mental arithmetic, estimation, and approximation and that substantially *less* be placed on paper and pencil execution of the arithmetic operations.
- That direct experience with the collection and analysis of data be provided for in the curriculum to insure that every student becomes familiar with these important processes.

We urge widespread public discussion of the implications of the changing roles of mathematics in society, support of efforts to develop new materials for students and teachers which reflect these changes, and continued and expanded experimentation within the schools.

With regard to the secondary school curriculum, in summary, we recommend:

- That the traditional component of the secondary school curriculum be streamlined to make room for important new topics. The content, emphases, and approaches of courses in algebra, geometry, precalculus, and trigonometry need to be reexamined in light of new computer technologies.

- That discrete mathematics, statistics and probability, and computer science now be regarded as "fundamental" and that appropriate topics and techniques from these subjects be introduced into the curriculum. Computer programming should be included at least for college-bound students.

Modern computer technology clearly has vast potential for enriching and enlivening the secondary school curriculum. However, we are not now in a position to make firm recommendations. There is need for research on the effects of incorporating technology into the traditional secondary school curriculum. We urge federal support for investigations into this question, including development of experimental materials and prototypes of actual school curricula.

Although we are generally optimistic about the future role of computers, we feel we must highlight one point that worries us even though it is not directly within our charge. The disparity of access between children who have a computer at home and children who do not, threatens to widen the educational gap that already exists between different economic strata. It is urgent that programs be designed to address this problem.

We clearly recognize that the most immediate problem is not the mathematics *curriculum*, but the need for more, and better qualified, mathematics *teachers*. One section of this report is devoted to recommendations on attracting and training prospective teachers, better utilizing the talents of in-service teachers, and retraining teachers who are inadequately prepared for teaching mathematics. We feel that the coming changes in subject matter and emphasis not only will bring a new sense of vitality to K-12 mathematics, but also will encourage teachers actively to seek and participate in programs of professional development.

The Conference Board of the Mathematical Sciences stands ready to assist efforts to develop immediate strategies for addressing the teacher shortage and to develop long-term strategies for bringing about the curricular changes envisioned in this report.

I. THE NSF/CBMS MEETING

In response to suggestions made at the July 9, 1982 meeting of the NSB Commission on Precollege Education in Mathematics, Science and Technology and, specifically, to a request made by the Educators Panel of the Commission, The Conference Board of the Mathematical Sciences (CBMS) held a special meeting to address the topic THE MATHEMATICAL SCIENCES CURRICULUM K-12: WHAT IS STILL FUNDAMENTAL AND WHAT IS NOT. The meeting was held on September 25-26, 1982, at the headquarters of the Mathematical Association of America in Washington, D.C.

11

Participants in the meeting included the presidents of the American Mathematical Society, National Council of Teachers of Mathematics, Mathematical Association of America, American Mathematical Association of Two-Year Colleges, and Society for Industrial and Applied Mathematics. Two members of the Commission, Frederick Mosteller and Katherine Layton, and two members of the Commission staff, Ray Hannapel and Mary Kohlerman, also participated in the meeting. The other participants were representatives of the CBMS constituent organizations and the CBMS officers. (The list of meeting participants is in Appendix A.)

Six position papers on the fundamentals in the mathematics curriculum were written expressly for this conference. These position papers, along with various other background materials were distributed to all participants prior to the meeting. (Copies of the position papers are in Appendices D and E. A list of other materials is in Appendix E.)

The initial portion of the meeting was devoted to discussion of the position papers. Following this, participants joined working groups to address the question of what is still fundamental and what is not in K-8 and in secondary school mathematics. A general discussion of the written reports of the working groups was held during the last hours of the Saturday session.

On Sunday, new working group assignments were made to discuss the implications of changes in the K-12 mathematics curriculum. The reports from these groups were discussed in the closing session of the conference.

II. RECOMMENDATIONS TO THE COMMISSION

INTRODUCTION

In the limited time available during the conference, it was not possible to establish full consensus on every detail of the working group reports. However, there clearly was broad consensus on the need to incorporate calculators and computers, as well as additional data analysis, into the K-12 curriculum and to make the necessary adjustments in the mathematical topics and modes of thought traditionally taught at these grade levels.

Some detailed recommendations on the fundamentals in the K-8 curriculum, what should be emphasized *more* and what should be emphasized *less*, are given in the working group report, "Elementary and Middle School Mathematics." The corresponding adjustments needed in the secondary school curriculum, where the impact of technology is even greater, are described in more general terms in the two reports, "Traditional Secondary School Mathematics" and "Non-traditional Secondary School Mathematics." In this area much more investigation and experimentation are required before a firm consensus can be reached.

Recommendations on dealing with the challenge of providing children with access to, and understanding of, computers and calculators pervade this entire report. They are dealt with specifically in the report, "The Role of

Technology." A statement of the relationship between the mathematics curriculum and what is, or can now be, taught in other disciplines is given in the report, "Relations to Other Disciplines." The report, entitled "Teacher Supply, Education, and Re-education," contains a variety of recommendations on attracting and retaining well-qualified mathematics teachers.

The question of the total time in the school curriculum which should be devoted to the study of the mathematical sciences was not addressed in any detail at the meetings. The general feeling was that, at the primary level, there appears to be an approximate balance between topics needing more emphasis and those needing less. At the secondary level, it is not yet clear how much time, in addition to the time that can be gained by streamlining the traditional mathematics curriculum, will be needed for discrete mathematics, probability and statistics, and computer science. This can only become clear after detailed examination of model mathematical sciences curricula and careful consideration of the many competing demands for time in the overall school curriculum.

There was general agreement at the conference that the most pressing immediate problem is the need for more, and better qualified, teachers in the classrooms. No curriculum, no matter how well-founded, can possibly succeed without dedicated and competent teachers to teach it. However, many participants felt that appropriate changes in the curriculum at this time, rather than detract from efforts to deal with the teacher shortage, could bring a new sense of vitality to K-12 mathematics and could serve to encourage teachers to actively seek and participate in programs of professional development.

Participants in the conference were also in agreement that their suggestions, even if influential in full, cannot be expected to constitute a "cure-all" for all the shortcomings of K-12 mathematics. In fact, a fundamental improvement in K-12 mathematics can be hoped for only within the framework of a general improvement of the total school environment. Remedies for the difficulties facing the teaching community (low teachers salaries, low prestige, lack of support by society, lack of discipline in the classroom, irregular attendance, etc.) are societal in nature and fall outside both the mandate and the competence of this group.

SOME ADDITIONAL RECOMMENDATIONS

In addition to the concerns and recommendations in the working group reports, a few points were emphasized in the general discussions which are of vital importance in the implementation of any curricular changes:

- Textbooks

Textbooks play a key role in the mathematical sciences curriculum at all levels. Any major changes in the curricula at the elementary, middle, or high school levels must be accompanied by corresponding changes in textbooks. For this to happen, the groups responsible for preparing textbook series and for adopting textbooks must have substantial subject matter competence and have available to them direct evidence of textbook effectiveness.

- Testing

To a large extent the grade and high school teachers are under strong pressure to train their pupils so as to maximize their chances of doing well on standardized tests. As long as these tests stress computations, the pupils are bound to be drilled in computations, regardless of any other guidelines the teachers may have received, and even contrary to the sounder convictions the teachers themselves may have.

We call the attention of the Commission to the power and influence of standarized tests. Properly modified, these can have considerable effect in hastening the hoped-for improvements in the teaching of mathematics in grades K-12.

- Articulation

The entrance requirements and course prerequisites of the nation's colleges and universities are major factors in determining the topics in the secondary school curriculum as well as the amount of time devoted to them. Efforts to change the curriculum at the secondary level must be carried out in a cooperative effort with the colleges and universities.

- Equal Access

The disparity of access to computers between children who have a computer at home and children who do not threatens to widen the educational gap that already exists between different economic strata. This disparity is exacerbated by the differences in resources available to different school systems. It is urgent to design programs to address this problem.

- Women and Minorities

The conference noted with satisfaction the improvement during recent years in the participation of women in upper secondary mathematics. The many efforts that have led to this improvement must continue to be supported. We look forward to corresponding success with minority and handicapped students and continued improvement in the participation of women.

WORKING GROUP REPORT: ELEMENTARY AND MIDDLE SCHOOL MATHEMATICS

Arithmetic and, more generally, quantitative thought and understanding continue to become more important for more people, but the importance of various aspects of arithmetic has changed and will continue to change as computers and calculators become pervasive in society. The suggestions below are designed better to equip students for life and effective functioning in the developing age of technology. We believe implementation of these suggestions into the K-8 curriculum will make students more adaptive to future change, better equipped to use modern technology, better grounded in the mathematical bases for other sciences, and better grounded for further school mathematics.

A principal theme of K-8 mathematics should be the development of number sense, including the effective use and understanding of numbers in applications as well as in other mathematical contexts.

The changes we propose are fairly substantial, but are primarily in emphasis rather than in overall content. We believe they are consistent with, and are natural outgrowths of, recommendations relative to K-8 education of the earlier valuable documents, *Basic Mathematical Skills* by NCSM and *An Agenda for Action* by NCTM.

When implemented, the desired changes at the K-3 level lead to even more significant improvements at the 4-6 and 7-8 grade levels. They essentially replace excess drill in formal paper-and-pencil computations with various procedures to develop better number sense on the part of the student.

Here is a list of special concerns:

1) Thorough understanding of and facility with one-digit number facts are as important as ever.

2) The selective use by students of calculators and computers should be encouraged, both to help develop concepts and to do many of the tedious computations that previously had to be done using paper and pencil.

3) Informal mental arithmetic should be emphasized at all levels, first aimed at exact answers and later at approximate ones. Such activity is necessary if students are to be able to decide whether computer or calculator printouts or displays are reasonable and/or make sense. Informal mental arithmetic involves finding easy, not formal algorithmic, ways of looking at number relationships.

4. There should be heavy and continuing emphasis on estimation and approximation, not only in formal round-off procedures, but in developing a feel for numbers. Students need experience in estimating real world quantities as well as in estimating numerical quantities which appear in complicated form. Methods requiring explicit (right or wrong) answers should be used where possible to help develop estimating procedures. For example, many exercises on comparing complicated fractions with easy ones (e.g., 12/25 with 1/2, and 103/299 with 1/3) can be used to get students to think of complicated fractions as close to, but less than (or more than), easy fractions.

5) There should be a heavy and continuing emphasis on problem-solving, including the use of calculators or computers. Trial and error methods, guessing and guestimating in solving word problems should be actively encouraged at all levels to help students understand both the problems and the use of numbers. Naturally, examples and illustrations should be appropriate to the students' age, interest, and experience.

6) Elementary data analysis, statistics, and probability should be introduced, or expanded in use, including histograms, pie-charts, and scatter diagrams. The understanding and use of data analysis is becoming a vital component of modern life. The collection and analysis of data should include personal data of meaning to students, e.g., number of siblings, students' ages, heights and weights, data

culled from newspapers, almanacs, and magazines, random data such as that produced by urn schemes and data from experiments in other school subjects.

7. Place value, decimals, percent, and scientific notation become more important. Intuitive understanding of the relative sizes of numbers that arise in the everyday world of applications becomes even more vital.

8) More emphasis on the relationship of numbers to geometry including, for example, number lines and plotting, should lead to better understanding of the concepts of arithmetic and of geometry.

9) Understanding of fractions as numbers, comparison of fractions, and conversions to decimals should have more emphasis while drill on addition, subtraction, and division of numerical fractions with large denominators should have less.

10) Drill on the arithmetic operations on three- (and larger) digit numbers should be de-emphasized. Such computations can and should be done by calculators and computers.

11) Intuitive geometric understanding and use of the mensuration formulas for standard two- and three-dimensional figures should be emphasized. More stress on why the formulas make sense is needed.

12) Function concepts including dynamic models of increasing or decreasing phenomena should be taught. (For more details, see 8 in "Traditional Secondary School Mathematics.")

13) The concepts of sets and some of the language of sets are naturally useful in various mathematical settings and should be used where appropriate. However, sets and set language are useful tools, not end goals, and it is inappropriate to start every year's program with a chapter on sets.

14) Based on motivation from arithmetic, algebraic symbolism and techniques should be encouraged, particularly in grades 7 and 8.

15) More extensive use of mathematics and computers in many other subjects including business, languages, social science and science courses should be actively pursued. We encourage the consideration of this matter by experts in these fields and welcome opportunities to collaborate on further work in this area.

A discussion of possible computer programming or computer literacy courses is left to other groups for further study.

We call the Commission's attention to the fuller discussions and comments related to the K-8 curriculum in various position papers discussed at this conference including those of Anderson, Hilton, Pollak, and Willoughby.

Implementation Concerns

1) We hope the Commission will encourage widespread public discussion of the implications for K-8 mathematics of the changing roles of

arithmetic in society. As an early step, we suggest discussions and conferences between teachers, supervisors, mathematics educators, mathematicians and editors of textbook series concerning this report and others on the same general topic. Such conferences could be quite inexpensive if most participants are local.

2) We hope the Commission will seek ways to encourage the development and use of textbooks for students and of teacher-training materials in the spirit of the suggestions made above.

3) We hope the Commission will seek ways to encourage changes in standardized tests toward number sense and problem-solving and away from single-operation computational skills.

4) We hope the Commission will encourage school systems to reassign interested teachers at the 4–6 grade level to become specialists at teaching mathematics or other disciplines. One mode might be a simple trade of classes between teachers with each teacher concentrating in areas of particular interest and competence. The needed changes in subject matter emphasis will be much easier to effect if those actually teaching any subject are selected for their special interests and aptitudes. Special inservice training programs should be developed for all such semi-specialized teachers, whatever their subject.

5) We hope the Commission will seek ways to improve the status of teachers and the conditions under which teachers attempt to do the important and difficult job of educating future citizens.

6) We believe that the needed changes can be brought about somewhat gradually and with general support of those concerned. There already is discussion in teacher and supervisor groups concerning many of the ideas put forth here. The proposed changes generally involve modifications in the way mathematics is introduced and used in schools rather than adding new subject matter. The changes should permeate texts and not just be add-ons that can be ignored. There appears to be an approximate balance in time between topics needing more emphasis and those needing less. With the exception of computer use and the possible exception of parts of data analysis, the topics needing added emphasis have been taught and learned in American schools at various times and places in the past. The diminished role of paper and pencil computation is perhaps the topic which will provoke most concern and possible disagreement.

WORKING GROUP REPORT: TRADITIONAL SECONDARY SCHOOL MATHEMATICS

Current secondary school mathematics curricula are organized into separate year-long courses covering algebra, geometry, and precalculus topics. There are proposals that challenge this traditional division of school mathematics and the position of calculus as the primary goal for able college-bound students. Thus, the following analysis used conventional course headings for discussion of proposed changes in traditional topics, not as endorsement of the *status quo*.

1) *Overall Recommendation*

The traditional component in the secondary curriculum can be streamlined, leaving room for important new topics. However, since breakthroughs in technology which allow this streamlining are so recent and the conceivable implications so revolutionary, it is not yet entirely clear what specific changes are appropriate.

2) *Algebra*

The basic thrust in Algebra I and II has been to give students moderate technical facility. When given a problem situation, they should recognize what basic algebraic forms they have and know how to transform them into other forms which might yield more information. In the future, students (and adults) may not have to do much algebraic manipulation—software like mu-Math will do it for them—but they will still need to recognize which forms they have and which they want. They will also need to understand something about why algebraic manipulation works, the logic behind it. In the past, such recognition skills and conceptual understanding have been learned as a by-product of manipulative drill, if learned at all. The challenge now is to teach skills and understanding even better while using the power of machines to avoid large time allotments to tedious drill. Some blocks of traditional drill can surely be curtailed, e.g., numerical calculations using look-up and interpolation from logarithm and trigonometry tables.

3) *Geometry*

A primary goal of the traditional Euclidean geometry course is to develop logical thinking abilities. But not every fact need be given a rigorous proof to pursue this goal. Nor need this be the only goal of geometry, nor geometry the only means towards this goal.

We recommend that classes work through short sequences of rigorously-developed material, playing down column proofs, which mathematicians do not use. These proof sequences should be preceded by some study of logic itself. Important theorems not proved can still be explained and given plausibility arguments, and problems involving them can be assigned. The time which becomes available because proofs are de-emphasized can be devoted to study of algebraic methods in geometry, analytic geometry and vector algebra, especially in three dimensions. Work in three dimensions is essential if one is to develop any pictorial sense of relations between many variables, and handling many variables is essential if one is to model phenomena realistically.

There is much room for using computers in geometry. The power of graphics packages makes it much easier for students to get a visual sense of geometric concepts and transformations. The need to use algebraic descriptions of geometric objects when writing graphics programs reinforces analytic geometry. Finally, the algorithmic thinking needed to write programs bears much resemblance to the thinking required to devise proofs.

4) *Precalculus*

What often happens in this course is that students see the same topics yet another time, with more drill but with little new perspective. For better students there may not be a need for a precalculus course if drill is no longer so important and if algebra and geometry are done "right," with the concepts made clear. For instance, one justification for the precalculus course is the perceived need to develop the idea of functions; functions appear in Algebra I and earlier, but current teaching may give too static an understanding. With computers, the concept of function can be made central earlier and more clearly. The computer supports qualitative analysis of the graphs of functions, in a dynamic mode of display, and also allows detailed analysis of zeros, rates of change, maxima/minima, etc.

5) *Algorithmics*

Computers and programming have made the creative human talents and skills involved in developing and analyzing algorithms extremely important. These talents and skills, emphasized by the group on non-traditional topics, can be exercised quite naturally through traditional topics as well. Much of high school algebra consists of systematic methods for handling certain problems, e.g., factoring polynomials. Such methods are algorithms. Instead of making the student carry out such methods with paper and pencil a boring number of times, have the student do it just a few times and then program a computer to do it. The understanding gained should be at least as great.

6) *The Average Student*

For the many students in secondary school who are not specially talented in mathematics and not headed for careers in science or technology, current programs are a source of discouragement, anxiety and repetition in a dull "basic skills" program which serves them poorly. We cannot ignore the needs of this large and important group. Computers, as mathematical tools and media of instruction, offer a fresh window into mathematics for them.

7) *Cautions*

We have suggested that technology provides an opportunity to devote less time to traditional techniques while boosting understanding and allowing more time for more complex, realistic problem-solving. However, there are several cautions. First there are widespread and deep reservations about how much traditional goals should give way to technology. Second there is little research data on the feasibility of such changes, and there are almost no prototype school curricula embodying the new priorites. Experimental programs, and research on the results, must be given major support. Third, changes in secondary programs must be carefully articulated with the expectations of colleges and employers, who often have conservative views about curricula. Finally, the syllabi of an extensive range of standardized tests play a very influential role in setting curricula and the actual classroom emphases of teachers. If curricula are to change, the tests must be changed. Clearly, strong national leadership and cooperation are necessary, from teachers, mathematicians and public policy-makers, to meet these challenges and implement significant change.

WORKING GROUP REPORT: NON-TRADITIONAL SECONDARY SCHOOL MATHEMATICS

On two basic principles the panel was unanimous:

—There is need for substantial change in both the subject matter of and the approach to teaching in secondary school mathematics.

—If changes are to be made in secondary school mathematics, we must make haste slowly, taking care at all times to insure full consultation with and support from the secondary school mathematics teaching community.

Our specific recommendations are grouped under five headings: Subject Matter, Approach to Teaching, The Use of New Technology, Teacher Training and Implementation.

1) *Subject Matter*

Careful study is needed of what is and what is not fundamental in the current curriculum. Our belief is that a number of topics should be introduced into the secondary school curriculum and that all of these are more important than, say, what is now taught in trigonometry beyond the definition of the trigonometric functions themselves. These topics include discrete mathematics (e.g., basic combinatorics, graph theory and discrete probability), elementary statistics (e.g., data analysis, interpretation of tables, graphs, surveys, sampling) and computer science (e.g., programming, introduction to algorithms, iteration).

2) *Approach to Subject Matter*

The development of computer science as well as computer technology suggests new approaches to the teaching of all mathematics in which emphasis should be on:

—algorithmic thinking as an essential part of problem-solving

—student data gathering and the investigation of mathematical ideas in order to facilitate learning mathematics by discovery.

3) *Technology*

New computer technology allows not only the introduction of pertinent new material into the curriculum and new ways to teach traditional mathematics but it also casts doubt on the importance of some of the traditional curriculum, just as the hand calculator casts similar doubts about instruction in arithmetic. Particularly noteworthy in this context at the secondary level are:

—Symbolic manipulation systems which even now, but certainly far more in the near future, will allow students to do symbolic algebra (and calculus) at a far more sophisticated level than they can be expected to do with pencil and paper.

—Computer graphics and the coming videodisc systems which will enable the presentation and manipulation of geometric and numerical objects in ways which should be usable to enhance the presentation of much secondary school mathematical material.

One caveat which we would stress is that this technology and related software packages must be used not to enable students to avoid understanding of the essential mathematics but rather to enhance such understanding and to allow creative experimentation and discovery by students as well as to reduce the need for tedious computation and manipulation.

4) *Teacher Training*

There are two aspects of this, both dealing with secondary school mathematics on which we wish to comment:

a) Retraining of current teachers in the new topics, approaches and technology.
One possible new approach to this might be the use of college students to aid and instruct secondary school personnel as part-time employees and perhaps through such incentives as forgiveness of student loans.

b) Education of new teachers.
Crucial to long-term solution of the secondary school mathematics education problem is that the requirements for degrees in mathematics education be, as necessary, changed to incorporate modern content and approaches. In particular, we believe that all prospective teachers of secondary school mathematics should be required to take at least:

—one year of discrete mathematics in addition to traditional calculus requirements

—one semester or one year of statistics (with focus on statistical methods rather than mathematical statistics)

—one year of computer science.

5) *Implementation*

We recognize that the kinds of changes proposed here not only require much more study than has been possible by our panel but that also they will never be implemented unless there is dedicated cooperation among:

—secondary school teachers of mathematics and their professional organizations

—college curriculum people in schools of education and in mathematics departments and including their organizations

—state and local education authorities and their organizations.

A conference at an early date bringing together these groups to discuss the relevant problems and plan future action might be the most fruitful next step to provide some momentum for the changes we believe are necessary.

WORKING GROUP REPORT: THE ROLE OF TECHNOLOGY

Computers and related electronic technology are now fundamental features of all learning and working environments. Students should be exposed to and utilize this technology in all aspects of school experience where these devices can play a significant role.

We recommend:

1) The potential of technology for enhancing the teaching of mathematics and many other subjects is vast. Development of such resources should be supported at a national level. Specific examples include computer-generated graphics, simulations, and video-disc courseware materials. There should be efforts to create a network providing easy access to such banks of material.

2) While computing technology offers promise to enhance learning, differential access to the benefits of that technology could widen the gaps in educational opportunity which already separate groups in our society. It is imperative that every effort be made to provide access to computers and their educational potential for all sectors of society.

3) As a general principle, each mathematics classroom should have available computers and other related electronic technological devices to facilitate the computing and instruction required for mathematics learning and competency. Such availability of computers and other electronic technological devices in the mathematics classroom is as important as the availability of laboratory equipment for science instruction.

4) Hand calculators should be available in mathematics classrooms (both in elementary and secondary schools) for students on the same basis that textbooks are now provided.

5) Support should be given for broad developments in software that may be useful in the schools. School districts should encourage their teachers and students to engage in cooperative development activities and to find ways to recognize and disseminate the products of those efforts.

6) Computer literacy involves not only the use of computers to accomplish a great spectrum of tasks but also a general understanding of the capabilities and limitations of computers and their significance for the structure of our society. Development and implementation of appropriate programs to teach these more general concepts should be supported.

7) Possible curricular changes emanating from technological changes will require careful study and deliberation over a long period of time. This activity must be encouraged and supported from a national level. The exploratory projects should bring together teachers, curriculum developers, mathematicians, and affected interested parties from business and industry. The new programs developed should be tested extensively in a variety of settings to insure that they work with real students and schools before extensive implementation is attempted.

8) The interplay between word-processing, computers, data bases, and data analysis methods assists in breaking down barriers between disciplines, thus offering an opportunity for schools to provide a range of holistic problem-solving experiences not typical in school today. Using the technology as an aid, students can plan and conduct data collection, analysis, and report writing that is realistic, attractive, and far beyond normal expectations in today's schools.

9) The need for well-trained, highly qualified teachers of mathematics is a must in a technological society. Support should be given to organizing programs for inservice training and retraining of current teachers of mathematics (elementary and secondary) who are inadequately prepared to teach a technologically-oriented curriculum, but have the capacity to profit from such programs to strengthen their mathematical preparation and teaching skills.

10) While technology provides opportunities, it also makes demands. The world becomes a more complex place in which to live. If we are to insure that a broad spectrum of society can function and participate actively in the business/industrial community and decision-making of the country, it is imperative that students become adept in the precise, systematic, logical thinking that mathematics requires.

WORKING GROUP REPORT: RELATIONS TO OTHER DISCIPLINES

Along with the effects of computational technology on the mathematics curriculum, it is also necessary to consider how this technology and the proposed curricular changes affect the relationships between the curricula in other disciplines and the curriculum in mathematics. We have interpreted the phrase "other disciplines" rather broadly.

First, using a narrow view, we must look at the effects these curricular changes will have on science education. There has always been a necessary interaction and coordination between the science and mathematics curricula, particularly with the physical sciences. At a minimum, this revised curriculum, which encourages student use of calculators and computers and emphasizes a good sense of estimation, provides an opportunity for elementary and high school education to be more realistic and eliminates the use of specialized problems with "easy numbers." If we raise our sights a bit, there is an opportunity for a better coordinated and integrated total science education. Furthermore, the introduction of statistical ideas, data handling procedures, and discrete mathematics provides an opportunity for a more mathematical discussion of social science problems at the elementary and high school levels. Similarly, changes in currently available tools will undoubtedly affect courses in business and commercial programs.

Related questions arise on the other side. What do the school programs and the college programs in natural sciences, social science, and business require in the mathematical preparation of entering students? We believe the suggested curriculum can only be an improvement, but discussions with leaders of those disciplines is required.

Taking the broad view, we also believe that this modified curriculum, which provides students with the same (or greater) ability to use mathematics as well as an ability to use and appreciate the technology, will provide for a wiser citizenry. The graduates of such a program should be better equipped to deal with "poll results" and statistical data references to the economy and sociological problems.

We believe there is one serious area in which the nation needs more data for the development of an appropriate mathematics curriculum. Namely, what are the needs, in terms of mathematical skills, of the students who seek technical vocational employment without going on to further schooling? Furthermore, what are the mathematical needs of students going on to technical or vocational schools? Although we do not know the answer, we believe the new curriculum will do at least as good a job as the existing one. A conference or meeting to explore this area would be an excellent idea and would complement our work.

WORKING GROUP REPORT: TEACHER SUPPLY, EDUCATION, AND RE-EDUCATION

Efforts to improve and up-date the mathematics curriculum and to increase the mathematics, science, and technology literacy of all citizens requires the support of qualified mathematics teachers at all levels. At present there is a serious and well-documented shortage of qualified teachers of mathematics at the elementary and secondary school levels in most areas of the country. Economic, employment, and social conditions forecast that the current short supply may indeed be a long-term problem. Furthermore, even in geographic locations where adequate supplies exist, the frequent turnover of mathematics teachers tends to impede learning.

The following recommendations address the need to increase the supply of mathematics teachers as well as to improve the qualifications of the teacher and thereby, the learning, of mathematics:

1) While state and local efforts by industry, business, and academe to deal with the teacher shortage are laudable and should continue, the magnitude of the problem is national in scope. An articulated national commitment with federal leadership and support is needed for its resolution. The public should be made aware of the problem through more effective publicity.

2) Incentives of all types need to be studied to *attract* and *retain* qualified teachers of mathematics. Financial incentives should be given special attention with priority assigned to those which do not create undue inequities and tensions among colleagues, in order to avoid being counterproductive.

Examples of possible incentives and support systems include the following:

- a) Forgiveness of student loans and/or interest on loans for those who enter the teaching field.
- b) High entry level salaries for special expertise (e.g., computer training).
- c) Reduced teaching loads to allow teachers to pursue graduate study or other advanced training in the mathematical sciences and applied areas.
- d) Financial support of graduate study or other advanced training in the mathematical sciences and applied areas.
- e) Salary differentials by discipline.
- f) Summer positions and other cooperative arrangements with business and industry to supplement a teacher's income (with the obvious caveat that the short supply of teachers is largely due to the fact that higher industrial salaries lure teachers away; industry would have to be discouraged from using this arrangement for recruitment purposes).

3) In an era when content and technology are changing so rapidly, incentives are needed to keep qualified teachers in the field abreast of current trends in the mathematical sciences. Inservice workshops, NSF-type institutes, retraining courses, industrial experiences, and other forms of continuing education can serve to refresh the faculty and renew their commitment to teaching.

4) In some parts of the country, teachers from other disciplines are being assigned to teach mathematics classes. These teachers need considerable subject matter training and assistance in developing appropriate teaching strategies in order to reach a level of preparation close to that of regular mathematics teachers and succeed in their new assignments.

5) Encouraging colleges and universities to loan their faculty, and business and industry to loan their mathematically-oriented employees to teach courses in the secondary schools could be mutually beneficial. Qualified retirees or near-retirees might also be recruited to enter the teaching field. (Of course, the issues of appropriate teacher training and certification need to be addressed.)

6) In states where this is not the norm, it is recommended that teacher certification requirements be stated in terms of the specific topics to be covered in the subject area rather than in terms of just total number of credits.

7) Recommendations regarding the mathematical fundamentals to be covered in educating qualified teachers of mathematics include:

a) Elementary Level

It is strongly suggested that mathematics at the elementary school level be taught by teachers who specialize in mathematics. Whether the teacher specializing in mathematics should be assigned to all grades or just to grades 4-6 (or 4-8) requires further study. An alternative approach would be to identify those teachers in a given school who most enjoy teaching mathematics. Those teachers could be assigned to teach all mathematics courses across a grade level, while other teachers do similarly in reading and writing.

The following recommendations pertain to both the regular elementary school teacher and the teacher specializing in mathematics:

For entry into the mathematics education program for elementary school teachers, at least three years of college-track mathematics in high school is recommended. College mathematics courses should provide a sufficient background to understand the relationships between algebra and geometry, functions, elementary probability and statistics, instruction in the use of the hand-held calculator, and some exposure to computers. Creative approaches to problem-solving should also be included in the curriculum. Training should be at least one level above what is being taught. This background is particularly important in light of children's awareness of the world around them through television, other media, computers, and so on.

b) Secondary Level

Secondary school mathematics teachers should have course work in mathematics equivalent to a major in mathematics. Requirements for those who will teach mathematics should include the equivalent of a two-year calculus and linear algebra sequence, discrete mathematics, probability and statistics, and appropriate computer training. These courses should develop in the student a sense of "mathematical maturity" in the approach to problem-solving.

Conclusion

The recommendations cited here require careful planning and implementation. With high technology a mainstay of our present and future society, it is imperative that we recognize and promote mathematics as a powerful, useful, and enjoyable component of our lives.

The reader is referred to the following documents for additional information:

Precollege Teacher Training and Retraining in Light of Expected Changes in School Mathematics. Richard D. Anderson, September 16, 1982.

Testimony Presented to the National Commission on Excellence in Education. Henry L. Alder, March 11, 1982.

Testimony Presented to the National Commission on Excellence in Education. Harold D. Taylor, March 11, 1982.

Note: College and university curricula for educating mathematics teachers should be re-examined and revised in accordance with the above guidelines and goals. Contingency plans should be developed in case separate departments of mathematics and computer science are established at the secondary level in the future.

APPENDIX A

NSF/CBMS MEETING PARTICIPANTS
September 25-26, 1982

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APPENDIX B

AGENDA NSF/CBMS MEETING

THE MATHEMATICAL SCIENCES CURRICULUM K-12: WHAT IS STILL FUNDAMENTAL AND WHAT IS NOT?

September 25-26, 1982

Saturday, September 25

9:00 a.m.-9:30 a.m.	Opening Remarks, Henry Pollak The NSB Commission, Katherine Layton and Frederick Mosteller	Begle Room
9:00 a.m.-10:00 a.m.	General Discussion Session: The Position Papers	Begle Room
10:30 a.m.-10:45 a.m.	Break	
10:45-12:00 noon	General Discussion Session: The Position Papers (continued)	Begle Room
12:00 noon-1:00 p.m.	Lunch	
1:00 p.m.-2:00 p.m.	General Discussion Session: The Position Papers (continued)	Begle Room
2:00 p.m.-3:30 p.m.	Working Group Sessions	Conference rooms
3:45 p.m.-5:00 p.m.	General Discussion Session: The Working Group Papers	Begle Room

Sunday, September 26

8:30 a.m.-9:00 a.m.	General Discussion Session: New Working Group Topics	Begle Room
9:00 a.m.-10:30 a.m.	Working Group Sessions	Conference rooms
10:30 a.m.-10:45 a.m.	Break	
10:45 a.m.-12:30 p.m.	General Discussion Session: The Working Group Papers and The Report to NSF	

SOME COMMENTS ON THE AGENDA

Henry Pollak

The proposal under which this meeting is being funded states the following. "The purpose of this meeting is to provide the NSB Commission with advice and guidance from leaders in the mathematical sciences community on the changes that are needed to bring the nation's mathematical sciences curriculum (K-12) into the age of technology. While CBMS cannot hope to produce a final definitive document from a single meeting, we do think it is possible to identify some general principles, to formulate those questions most in need of further investigation, and to propose some mechanisms for conducting such investigations."

The word "curriculum" in this should not be narrowly construed. It includes questions of subject matter, of pedagogy, of teacher qualifications and teacher education, of relations to other disciplines and of the relationship to technology. We want to look into all of these at this meeting and pull together our knowledge and our views. In some cases, we will be able to give some pretty definitive answers; in others we will formulate questions in urgent need of further investigation and proposed mechanisms for undertaking such investigations.

In case you need convincing that there is enough work to keep us busy this weekend, here are some examples: Do we agree that estimation must have a much greater role in elementary mathematics than it has traditionally had? Do we agree that too much time is traditionally spent on arithmetic manipulations, and the hand-held calculator should have a major effect on the curriculum (in the broad sense that I have used the term)? What about the future of the material and of the point of view on symbolic algebraic manipulations in secondary school? What is the place of data analysis in the schools? What about decision making, statistics, algorithms, discrete mathematics, and probability? What about microprocessors and video discs and graphics terminals?

Why have we organized the Conference the way we have? We have position papers on many topics, and the next item of business will be to discuss them. After that, we have to break up into smaller groups, roll up our sleeves and get to work. It seemed to us that we should first break up by school level and then, using the results of the first discussions, break up again by some of the major issues on which our advice will be so important. We are going to ask each of you to give us your preferences within Working Groups A and Working Groups B. On each topic we may have one or more working groups, depending on how many of you sign up. We will respect your preference, with the boundary condition that each topic does need to be covered. Each working group will come up with opinions, statements, conclusions and recommendations for the benefit of the entire group.

There is an interesting and in my opinion constructive contradiction in what we are trying to do. We have here an excellent group of knowledgeable, innovative people who we hope will have lots of original ideas in the areas up for discussion. On the other hand, we want also to take up and reach consensus in areas that recently have been much discussed, both by ourselves and others. The very important fact will be that this group representing the mathematical sciences community as no other can, has agreed. This says something different from an individual having come to a particular insight or conclusion. Both new ideas and affirmations of current ideas will be important to the NSB Commission.

There will be problems and issues on which our conclusion will be that further work is needed—and here is what form this might take. In some cases it will be further work which CBMS might undertake, in other cases it may be CBMS together with other organizations or individual organizations within CBMS. Such recommendations will also be part of our report to the NSB Commission. It is possible that additional efforts will indeed be undertaken as a result.

APPENDIX C

POSITION PAPERS BY MEETING PARTICIPANTS

Richard D. Anderson, *An Analysis of Science and Engineering Education: Data and Information*

Richard D. Anderson, *Precollege Teacher Training and Retraining in Light of Expected Changes in School Mathematics*

Richard D. Anderson, *Arithmetic in the Computer/Calculator Age*

James Baldwin, Position Paper

James M. Landwehr, *Memo on Activities of American Statistical Association*

Stephen Willoughby, Position Paper

APPENDIX D

POSITION PAPERS BY NON-PARTICIPANTS

Henry Alder, *List of Temptations to Resist*

Peter Hilton, *The Role and Nature of Mathematics: Implications for the Teaching of Mathematics Today*

Stephen White, *Notes on K-8 Math*

2 A REVISED AND INTENSIFIED SCIENCE AND TECHNOLOGY CURRICULUM GRADES K-12 URGENTLY NEEDED FOR OUR FUTURE

Report from a Conference on Goals for Science and Technology Education Grades K-12

Prepared by Earle L. Lomon, ***Massachusetts Institute of Technology***

EXECUTIVE SUMMARY

At the request of the NSB Commission on Precollege Education in Mathematics, Science and Technology the conference considered available data and analyses relating to the situation in science and technology education. The participants, broadly representative of the science and technology communities in education, research and application, reached the following conclusions and recommendations.

Science and technology in the United States is lacking in two critical areas:

a. The recruitment and training of enough competent scientists and engineers to maintain leadership in the technology so necessary to the nation's prosperity.

b. The nurturing in the general population of enough familiarity with science and technology facts and concepts and the facility with problem solving strategies needed so that every person can cope adequately with their personal lives, their work and their role as decision makers in our technological democracy.

Among the leading causes of the above problems are the following deficiencies in precollege science and technology education:

i. Too little classroom time in those subjects.

ii. Insufficient curricular materials that demonstrate the importance of science through applications, improve learning through the interest and involvement of the student, and cultivate the student's problem solving strategies.

iii. The decline in numbers of qualified science teachers and in students preparing for the profession. This is especially crucial in that rectifying items (i) and (ii) above will require more teachers with better training in teaching methods.

The recommended remedy for the problem (i) is to require science and technology studies for everyone almost daily from kindergarten through grade 11, approximately doubling the present exposure. Those students preparing for careers in science and technology would also be expected to take science courses in grade 12.

Rectifying the second deficiency requires the development of new curricular materials, and the wider use of some presently available materials, in which

scientific methods, concepts and facts are applied by the students to problems and situations which they can perceive as relevant. In the past decade such curricula have been shown to be effective in improving basic skills, cognitive strategy and attitude towards science and mathematics. Further research in the teaching and learning of science and mathematics can optimize the effectiveness of the new materials and should be encouraged. These materials should emphasize phenomena in the local environment for grades K-6, personal health and biology in grades 7-8, and community wide problems with scientific and technological aspects in grades 9-11. Updating of the discipline centered courses for grades 10-12 and the partitioning of time between these disciplines each of these years is recommended.

The severe science teacher shortage should be urgently addressed in two ways. First, by quickly providing in-service education in the content and the methods appropriate to the curriculum described above and by revising pre-service college courses to convey the curriculum's teaching method as well as content. Further preparation and technical support for the teacher should be provided through science specialists, regional centers, and by establishing contacts with professionals in research and industry.

Second, by recruiting and retaining more competent science teachers. The following recommendations will help in this task: (1) increased professional satisfaction from teaching better courses to interested students, (2) participation in curriculum development, and (3) additional pay justified by the need for more time for training and activities in curriculum development work, equipment maintenance and science fairs.

A strong, well planned support structure is needed to bring about the above improvements. Financial and planning support is required from federal, state, local and industrial sources. The importance of involving the research scientist in science education policy and development and the earlier successful experience of the National Science Foundation in science education improvement are compelling arguments for again channeling a major portion of support through that agency.

The establishment of a Joint Council on Science and Technology Education is proposed to formulate policy and monitor progress. A national center could be established under the Joint Council's direction to bring together the best people for policy discussions and research, to operate teacher institutes and to instruct the public.

Rapid implementation of the above recommendations is urgently needed. A beginning may be made in a few months using available funding, institutions and curricular materials. The program as a whole may take 10-20 years to implement.

The nation should recognize the importance and long range nature of science and technology education improvement by establishing and maintaining support structures of a permanent nature.

A more detailed list of the conference recommendations is in section IV.

To meet the challenge the schools must overcome two obstacles: (i) the shortage of good science and mathematics teachers, and (ii) a curriculum which fails to inspire our brightest students to enter science and engineering careers and to provide the whole population with the needed level of knowledge and appreciation of things scientific and technological.

In the late 50's and 60's we faced a similar educational crisis dramatically emphasized by the flight of Sputnik. The nation responded with many new initiatives in curriculum development and teacher training, particularly through programs fostered by the National Science Foundation's Education Directorate. Public support for these programs waned for a variety of reasons including the decrease in Scholastic Achievement Tests and National Assessment of Educational Progress scores and other measures of science and mathematics ability. Ironically we have since learned in recent research (see Voss, Bredderman) that the new curricula led to better achievement than the traditional curricula. Further analysis (Jones) shows that the declines were minor or absent in the elementary grades, and also in junior high school biology and among those high school students intending to pursue scientific, technological or business courses in college. These are the areas for which most of the new curricula were designed and thus they were by no means the cause of the declines in scores. The reasons may have originated in societal changes and awarenesses which affected the students' home and school environment, but in any case were not due to the new curricula (Layman). In fact, national test scores are now beginning to improve and the new curricula are playing a positive role in this change (Voss).

However the partial success of the curricular developments of the late 50's, 60's and early 70's by no means implies that we have adequate curricula for the present and future. The first wave of curriculum reform that began in the late 50's was directed at increasing comprehension of science concepts and less at motivation, awareness of relevance, and problem-solving strategies. The second wave beginning in the late 60's took advantage of what was learned earlier to correct many weaknesses and to provide material that brought more concrete experiences to mathematics and science learning and related it to the motivations of everyday life. This second wave was cut short in the mid 70's. Further experience and research since that time has indicated the need for further curricular improvements of importance. Much more is needed that illustrates the uses of science and technology and the power of scientific methods in tackling problems at all levels, personal, community and national. Motivation and process skills are not well enough represented in the available curricula. More material is needed which engages the student in complex, realistic problem solving activities and thus develops the higher level cognitive processes.

The critical shortage of teachers for mathematics and science in the schools will in the long run be alleviated by a curriculum which motivates and prepares students for science and technology-oriented careers. But in the short run, any intensification of mathematics and science education will make the shortage worse, while different emphases in curriculum content will widen the gap in teacher preparedness. Thus, of paramount importance are considerations which

I. CONFERENCE ORIGIN AND PROCEDURE

The Commission on Precollege Education in Mathematics, Science and Technology was established by the National Science Board and the Director of the National Science Foundation in April, 1982. It was charged with the development of a national action plan to improve the effectiveness of the mathematics and science education in the nation's public schools. Having commissioned several studies, reviewed many reports, and held several hearings over the past year the Commission is now convening conferences to consider the evidence and formulate recommendations.

The Conference on Goals for Science and Technology Education, Grades K-12 was one of these, convened at the request of the Commission's Task Force on Education. Individuals representing science and engineering societies of research and education, school science administrators and teachers, teacher educators and curriculum developers were invited to attend. Organizers and participants of the conference are listed in Appendix P. A collection of studies and position papers prepared in the last few years was distributed to the participants before and during the conference (see Bibliography, Appendix R). Thus the conferees were immediately able to discuss their views on the best solutions as described in section II. This led them to their own set of recommendations which are delineated in sections III and IV.

II. THE CRISIS IN SCIENCE AND TECHNOLOGY EDUCATION

As the health and prosperity of our society is derived more and more from technology, especially high technology, our future becomes increasingly dependent on the effectiveness of education in science and technology. Currently that education is failing us in two crucial aspects: (i) there is a developing shortage of the highly qualified scientists and especially engineers needed for today's research, industry and higher education, hindering our industries' productivity and competitiveness, and (ii) the scientific and technological literacy of the population is inadequate to cope with the tasks they must perform and the decisions they must make with respect to environment and human welfare concerns, as individuals and citizens in our technological world. While the former necessitates the training of more and better scientists, engineers and technicians, the latter requires a population sufficiently acquainted with scientific fact and technological applications and skilled in making decisions based on that knowledge.

Our elementary and secondary schools have a decisive role to play in rectifying the situation. They must encourage a larger number of youths to aspire to careers as scientists and engineers and better prepare themselves for college studies. The schools must prepare a much larger segment of the population to operate our technological tools, such as computers, at home and at work. In addition, the schools must provide the whole population with sufficient awareness of and insight into our technological world so that it can cope with the myriad ways in which technology affects private lives and the welfare of communities.

immediately attract more individuals into science teaching and offer more and better pre-service and in-service preparation.

Finally, the conference had to consider the climate of disarray in the support structure for education and its improvement. Negative public attitudes toward science and technology and toward our schools and their curriculum are reflected by lagging support at local, regional and national levels and by public pressures for change dictated by uninformed reactions. Hopefuly more recent positive trends in the public perception of the role of technology and science and new information about how youths learn are preparing the way for major support of healthy new initiatives. How the conference dealt with all these issues is described in the next section.

III. THE POINT OF VIEW OF THE CONFERENCE

The Need

Views at the conference were in agreement with the major thrusts of the conclusions of the documents in the bibliography (see Appendix R). In particular it was agreed that the schools were not now providing enough science in the early years to make a sufficient number of students aware of interesting science and engineering careers. Equally important, the science that is taught is too rarely demonstrated to be relevant to the concerns of the students at their particular stage of development. Only a relative few are turned on by the natural curiosity that traditionally motivates scientific careers. Even fewer students have the opportunity to see the power of scientific investigation which also stimulates interest. Furthermore, it is the applications of science in every walk of life which are likely to motivate young people to consider careers in engineering. Such an early and motivating curriculum is also essential in providing the population at large with the general information concerning contemporary science and technology necessary to their own welfare and their role in the larger community. For them as well as for future scientists and engineers it is important that problem-solving and decision-making skills be developed so that they can (i) cope with the complexity of the technological aspects which affect their lives and (ii) participate in a democracy where the masses influence decisions concerning the use of technology.

There exist some good curricula in the separate science disciplines for those students who reach the last years of high school with suitable interest and preparedness. These courses, however, may need updating to take into account recent changes in the fields (in biology, for example, the role of genetic engineering), the effective use of microcomputers, and the sharpening of students' problem-solving abilities. However, the chief difficulty here is the shortage of competent teachers.

The Curriculum

Given the above considerations the conference came to the conclusion that science and technology should be taught in every year at an appropriate level and should be required for at least eleven years of school (see Appendix H). The required curriculum up to and including the 10th grade should use what is now available and develop further material that will (i) demonstrate the relevance of science and technology to many important aspects of the students' lives and their community and (ii) develop the higher cognitive strategies of problem solving and decision making. It was agreed that these latter process skills are as basic to our needs as those of computation and communication. A science curriculum oriented toward practical issues, however, is also an excellent way of fostering those traditional basic skills. The introduction of practical problems which require the collection and manipulation of data, the communication of results and ideas and the formulation and testing of solutions or improvements (i) improves the use and understanding of calculation and mathematical analysis, (ii) sharpens the student's ability to communicate verbally and in written form with precision, (iii) develops the higher process skills, (iv) imparts scientific concepts and facts as related to their application, (v) develops a respect for science and technology and more generally for quantitative observation and thinking, and (vi) stimulates an interest in many to enter scientific and engineering careers.

The conferees were impressed by recent research in cognitive process and science teaching which has shown that curricular materials and teaching strategies that are application and activity-oriented and involve realistic problem solving produce improved results in learning content and process and in developing positive attitudes (Voss). They were further impressed by the research which identifies specific strategies that further enhance concept and process learning (Greeno) and urge close collaboration of researchers with curriculum developers.

At an early age children are interested in the natural phenomena around them. In adolescence they are particularly concerned about themselves, their changing bodies and developing personalities. For these reasons it is advocated that in grades K-6 the emphasis be on a hands-on approach focusing on natural phenomena and problems in the child's familiar environment. Science should be taught daily in most of these grades. This implies about twice as much time devoted to science than at present (Hurd). In grades 7-8 there is an excellent opportunity for stressing various biological, chemical and physical aspects of oneself as a human being (see Appendix C) and personal problems in which science and technology play a role (clothing, drugs, weight and physical fitness, etc.). The above scientific activities will also present scope for the development of skills in the quantitative analysis of data and hence in the use of the computer.

Emerging from adolescence, youths become more concerned with their role in the community, how successful they will be in the world, and what the world is like for all. Hence in grades 9-11 it is recommended that the curriculum be structured around the interaction of science and technology with the whole society. Examples of the kinds of problems to be investigated that integrate knowledge from engineering, physics, biology, earth science, chemistry and applied mathematics are presented in Appendix I. The courses in these grades would be as intellectually demanding as the traditional courses. The quantitative and problem-solving aspects will be of much higher level than what is usually described as a "general science" course for non-science students.

At the 11th grade level many students are making decisions about their future careers and it is at this time that disciplinary courses to provide background for college study are needed. In the 11th grade it is recommended that such options be available for students as an alternative to the science, technology and community curriculum described above, with more options available in the 12th grade. Of course other effective variations of options can be envisaged from 10th to 12th grade. In any case, the conference felt that more balance in the development of facility in the disciplines could be achieved if each discipline was taught for part of each year, for instance on the basis of three periods of biology and two each of chemistry and physics in grade 11 and three periods of physics or chemistry and two each of the other subjects in grade 12 according to the students' interest. Alternative schemes were a 3-2-2 balance over three years or a 3-1-1 over three years with only one year required of these students for the science, technology and community course. The offering of one semester elective courses in the science disciplines is another alternative to year long courses. The conference did not favor the omission of the proposed science-technology sequence in order that advanced-placement courses in the traditional sciences could be reached more rapidly.

Both the need for new materials and for about double the present science teaching staff would preclude the immediate implementation of the K-12 curriculum described above. It is estimated that full implementation would take about fifteen years. Many phases of the curriculum, however, could be implemented within a few years with available course materials and teachers, given immediate resources for teacher preparation. Much of the K-8 curriculum for a reduced total number of class hours and the conventional disciplinary courses in grades 10-12 can be implemented quickly. The science and technology course may be started with a one-year course and grow as materials, curricula and staff are developed.

Use of Technological Tools

The conference also considered the great advantages that can be brought into education through the use of new communication and computation technologies. Television and other audio-visual technologies can be used to stimulate thought, activities and problem solving, and to graphically illustrate worlds of place, size and complexity othewise difficult to access. Calculators and computers can provide the computational and modeling power necessary for solving problems of real interest and can develop new systematic thought processes. Consequently the frequent use of broadcast, closed-circuit television and videotape and the early introduction of calculators and computers (before grade 6) is envisioned (see Appendix J). It is realized, however, that great care must be taken to avoid the overuse and misuse of communication and computation technologies in education that may arise because of the fascination of the media and our lack of experience about their effects. In particular the conference was anxious that these tools not be used to replace the self-checking learning that comes from interaction with reality, nor to replace the teacher in the bulk of situations where the teacher's understanding of student response is important. Television programs and computer software need to be developed specifically for the recommended curriculum.

Informal Education

Given the importance in the recommended curriculum attached to the interaction of science and technology with the real, natural and social world, the conferees believed that contacts with the community and opportunities for informal education should be fostered (see Appendix G). Parents and experts visiting the schools in various capacities, the students going out into the community to investigate and improve situations, to intern or observe career situations, and to participate in tours arranged by museums, Audubon societies, industries, etc. would all be valuable. The use of these informal opportunities are particularly important where school curricula and staffing are still deficient.

Teacher Preparation

The rate at which science teachers are leaving the profession (4% per year to non-teaching jobs) and the decreasing number of student-teachers preparing for and entering science teaching (64% drop from 1971-1980) is causing a growing shortage of qualified teachers for today's classrooms (as documented in the paper by J. A. Shymansky and B. G. Aldridge). This has resulted in a substantial proportion of high school science classes being taught by teachers not qualified to teach science (9% in 1981). The proportion of unqualified teachers is growing each year because half of the newly assigned science and math teachers (in 1981) fall into that category. The problem is nationwide, only four state supervisors reporting an adequate supply of science teachers. The shortage of qualified science teachers may be worse in middle schools for which elementary certification is adequate in some states. Middle school teachers must also be skilled in nurturing the cognitive development of adolescents.

Thus the science curriculum already in place is being taught ineffectively in many cases because of the shortage of qualified teachers. The recommended increase in years of science courses for the whole population clearly exacerbates this situation. At the secondary level it implies a two-fold increase in science teachers. Further, it was recommended that there be a substantial number of science specialists at the elementary level to support the generalist teacher and also to teach classes in grades 4-6 (see Appendix L). In addition, many of the teachers already in the system will have to learn about the content and classroom methods appropriate to applications-oriented, problem-solving courses advocated by the conference. This clearly indicates that priority must be given to the recruitment, education and retention of science teachers.

To overcome the growing crisis in science teacher supply and qualification, the conference recommended a variety of forceful actions (see Appendices L and M). The first is the immediate availability of a large number of opportunities for in-service education. Qualified science teachers need courses which will update them in the use and effectiveness of the available curricula of the type recommended. The underqualified teacher needs such preparation and in addition needs courses in contemporary science and technology. Almost all teachers need to learn methods appropriate to teaching action-oriented and problem-solving material. Courses on the use of computers in science education are also important. In particular, the conferees recommended that teacher institutes be offered, structured to meet the above criteria, as soon as possible.

Ongoing support should also be provided to teachers of science. Various forms of support are described in Appendix N. Regional science teaching centers and hot lines to college scientists (see Appendix M) will help as well as more science specialists at district and state levels. The support of the school principal is very important. He or she must be well informed of the needs of a science and technology education program.

Pre-service education is the key to the supply of teachers for the full curriculum described. Immediate attention is needed to the redesign of college instruction to train teachers in the methods as well as the content of the type of science instruction advocated. It was felt that not only the college course content but also the form of instruction must better match the application and investigation-oriented approach the prospective teachers are expected to use in the schools. The close cooperation of science departments with schools of education is needed to provide education students with appropriate science courses.

In addressing the need to attact and retain more competent people in science teaching, the conferees agreed that increasing salaries needs consideration. Differential salaries for science and mathematics teachers pose problems of equity and can run counter to present union principles such as seniority. The severity of these problems, however, may be obviated by relating extra pay to extra training, participation in curriculum development, maintenance of science equipment, the supervision of students in science fairs, and similar duties. Several states are now experimenting with some form of differential pay and the conference encouraged expansion of such programs to other states in this critical situation. It was felt, however, that pay is not the only incentive. The program advocated will increase professional satisfaction through the increased importance of science teaching, its larger role in the schools, more student involvement and interest, and teacher participation in curriculum development.

Support for Improvement

Given the difficulty of accomplishing the changes the conference recommended, the support structures needed to make it possible must be considered. More financial support for science and technology education will be needed at local, state and national levels. At the local level support for more, better paid science teachers and specialists is needed, for new equipment and new curricular materials, and for teacher preparation in the new curricula. The states can also support the improvement of college courses for teachers, regional science centers for teacher training and curriculum development. At the federal level the funding of teacher training institutes and developmental projects in curriculum, learning research and in effective dissemination approaches is desperately needed to revive the science education enterprise.

The mathematics, science and technology education programs of the National Science Foundation from the late 50's to the early 70's met the first challenge of this technological age. In retrospect we see that it met it effectively, producing important improvements in our science education. Some of the promising work being done in the mid 70's was left hanging in mid-air, with development incomplete or without an adequate dissemination. Some of these materials fit well with the requirements of the proposed curriculum and could be utilized quickly. The conference recommended that most of the funds now in the fiscal '83 National Science Foundation education budget be used for teacher training institutes designed to meet the criteria discussed above, and that much of the rest be used to complete and disseminate the best of the curricula developed earlier.

The National Science Foundation structure provides a unique and valuable interaction between scientists and science educators. In the past this was very fruitful in producing high level, relevant and scientifically accurate science and mathematics curricula. It is urged that this powerful synergy and the expertise previously assembled by the National Science Foundation Education Directorate be utilized again. Other federal agencies which support the general education enterprise must also emphasize the needs of youth and our society for better education in science and technology.

The program for change that has been presented is a complex and massive one and will require much planning and monitoring. The formation of a Joint Council of Science and Technology Education was proposed for this purpose. This council could bring together representatives of industry, education and science to plan the use of financial and human resources. In addition to and as a part of its policy formation activities, it was recommended that it create and operate a National Center for Science Education. In such a center resources and talent can be brought together to plan and stimulate the necessary research on science teaching and learning; and based on a synthesis of the results, develop and test curricular materials and foster improved programs of teacher training. It may operate a laboratory school and/or work with nearby schools (see Appendix N). It can serve as a model for regional centers throughout the nation.

Finally, the conference believed strongly that improvement of education, all education, should be a long term national priority. Although it is hoped that substantial improvement can be made in 5-15 years, this does not imply that national attention and support can be decreased drastically after that time. That was a mistake of the post-Sputnik era which can be repeated only at our peril as a leading and prosperous nation. Not only do education research, development and classroom trials take several cycles of work to produce a near-maximum result, but changing social and technological circumstances will require continual adaption. There should be a continuing resolve to provide substantial and permanent support for that great individual and national resource, education.

IV. RECOMMENDATIONS

In the preceding section the conference's recommendations have been presented in the context of its view of the situation and its rationale for improvement. The reports of the conference working groups in Appendices A-O contain more detailed discussions of aspects of the problem, more specifics of the recommendations and many explanatory examples and comments. The groups met separately during the conference. Consequently their reports may conflict with each other in minor detail, and they contain a few recommendations which the conference as a whole did not have time to consider. In this section the main conclusions and recommendations of the conference are concisely listed for the convenience of the reader.

The Task

- Education in science and technology is of great importance to every individual who must cope with our technological world and take part in our democratic process.
- Education in science and technology is necessary to produce the scientists and engineers needed.
- Science and technology education is a "basic" for the modern world.
- There is an urgent need to extend and improve science and technology education in grades K to 12.

The Proposed Curriculum

- Science and technology education daily in every precollege year.
- Emphasis in grades K-6 on phenomena in the natural environment, collecting and processing data, a balanced physical and biological science program.
- Emphasis in grades 7-8 on biological, chemical and physical aspects related to the personal needs of adolescents and to development of quantitative analysis skills.
- Emphasis in grades 9-11 on the application of science and technology to the improvement of the community, local and national.
- Options in grades 11-12 for discipline-oriented career preparation courses, preferably with several disciplines taken each year rather than one science subject each year.
- Grades K-11 program be an integration of science and technology and practical mathematics.
- Introduction of concepts of technology, such as feedback, alongside concepts of science.
- Curriculum be organized around problem-solving skills, real-life issues, and personal and community decision making.
- Research in teaching and learning be applied to identify desirable characteristics of curricular materials and teaching methods.
- Coverage of what is basic in contemporary science and engineering concepts and methods.
- Provision for interaction with the community and with informal education centers.
- Implementation of the above curriculum in stages as new material and qualified teachers become available.

Use of Technological Tools

- Television, computers and similar technology be used to extend, not replace, real experiences.

- Television productions be provided that stimulate thinking and doing, and present phenomena not easily accessed in the school environment.
- Use of calculators and computers to process large amounts of data.
- Use of computers to model realistic situations.
- Development of logical procedures through programming structures.
- Development of computer software specific to curricular needs.

Measuring Achievement

- Formulation of standards for achievement in basic problem-solving skills and in science content.
- Evaluation of achievement by testing process skills and integrated knowledge as well as facts and concepts.

Teacher Recruitment and Education

- Science teachers be qualified as well as certified.
- Rapid design and implementation of teacher institutes and in-service courses to update and qualify teachers, with special emphasis on methods of teaching integrated science and technology and problem solving to the various age groups.
- Teacher institutes on content be started now for the presently unqualified science teacher.
- Development and implementation of pre-service courses which focus on instructional methods relevant for the prescribed curriculum and on basic science content.
- Modeling in college education courses the teaching techniques expected to be used in the precollege classrooms. This requires close collaboration of science and education departments.
- Middle school science teachers should be required to have specialist qualification.
- Preparation of elementary school specialist teachers in science for grades 4-6, and informing principals of the needs of a science and technology program.
- Encouragement of research on the training of teachers.
- Involvement of teachers in curriculum development locally, regionally and nationally.
- Consideration of differential pay for science teachers to attract scientifically and technically trained individuals to teaching.
- Differential pay be based on special training and special duties required for science teaching.

Support Structure for Science and Technology Education

- Increased financial and planning support from industrial, local, state and federal sources.

- A systems-oriented approach for overcoming the many obstacles to improved science and technology education.
- A leading role taken again by the National Science Foundation in science education improvement, building on the important connection it provides between the scientific and education communities and on its previous successful experience in education.
- Early allocation of funds in the National Science Foundation budget for education to appropriately designed teacher institutes and for completing, testing and implementing the best of its curricula that have been incompletely developed or implemented.
- Preparation and deployment of science specialist teachers to support the curriculum and classroom work of science teachers, to respond quickly to teacher needs for information, equipment, field trips, etc.
- Opening of regional science education centers for curriculum planning, development and dissemination, for teacher awareness and training, for evaluation and research, and for contact with the community through activities such as exhibitions and forums.
- Organization of a Joint Council on Science and Technology Education to recommend policy and monitor progress.
- Establishing a national center for science and technology education under the Joint Council which would bring together the best talent for varying periods of time to collect and analyze data on all aspects of the field, to conduct central research on science cognitive processes and learning, curriculum development and teacher training. It would have facilities for a science and technology museum, exhibitions, conferences and workshops. A laboratory school and/or collaboration with neighboring schools would enhance its development and testing of curriculum.
- National recognition that science and technology education is a long-term enterprise of great importance, requiring continuing support as well as urgent current action.

APPENDIX A

REPORT OF THE WORKING GROUP ON ELEMENTARY SCHOOL SCIENCE

Education in science is a basic in American elementary schools today. As science is the basic skill needed by students to explore and experience the natural and technological world, science education must start early and continue through a student's formal and informal education.

Tremendous strides have been made in elementary school science (K-8) teaching in the last two decades. Elementary school teachers recognize that to teach elementary school science effectively, there is a need for support, time and resources. Thus, the elementary group has developed a series of "absolutes" to meet the above needs. We believe these absolutes are the conditions necessary to bring about restoration and/or continued improvement in elementary science education through improved systems and teacher training to enhance the acquisition of basic skills by students.

Support Systems

1. Elementary teachers need TIME to teach science, to continue their education in science, and to prepare science lessons. A typical "elementary school day" should include science instruction based on a planned, stated program of studies.
2. Science does not exist outside of personal, societal and career goals and must be a part of decision-making processes at all of these levels.
3. Schools must involve adults, the community and the society in order for elementary school science teaching to be successful.
4. Elementary school principals need to be trained in the specific uses of support structures for the efficient use of time, the effective use of resources, and a conscious philosophy of teaching.
5. There must be support structures and personnel to assist teachers in teaching elementary science. All schools must provide specialists to assist teachers in the effective teaching of science, materials (of all kinds) essential for science teaching and support for preparing and using the materials.

Teacher Preparation

1. For elementary school science, there must be qualified, competent teachers who feel confident and therefore comfortable with science.
2. Teachers of science must have a sense of curiosity and a desire to continue learning. Teachers need to be learners.
3. There must be formal and informal ongoing staff development in science for elementary teachers.
4. Preparation for elementary school science requires more than science courses. It requires training in the methods for teaching science in the elementary school and in what is known about how children learn.
5. As emergency and ongoing funds become available for teacher training, a part of these funds should be explicitly set aside for elementary teacher education in science.

Teaching Basic Skills

1. Formal, systematic interaction with and observation of the real world are essential in elementary education. Elementary school science should provide much of this experience.
2. Basic skills in science include:
   - Recognizing problem situations
   - Developing procedures for addressing the problem
   - Recognizing and evaluating solutions to problems
   - Applying solutions
3. Schools must have standards for measuring the acquisition of basic skills in science, and teachers and students must be evaluated against these standards.
4. Evaluation of students must reflect a change from the learning of pure content to the acquisition of basic skills in science (concept skills).
5. A good elementary science program should be a planned set of experiences representing a balance among the disciplines, a daily lesson, and (frequently) involvement in hands-on experiences.
6. The natural environment of the school campus should be used frequently as a laboratory setting. The use of local natural resources and educational resources (museums, acquaria, etc.) should be encouraged.
7. Students should be taught basic skills and how to apply them to both science investigations and other elementary study areas. Emphasis on collecting and processing data

should allow the use of integrated skills, with objectives becoming more sophisticated at succeeding grade levels.

8. Teachers should be encouraged to capitalize on the high student interest in science ideas and materials by using science as the vehicle for teaching reading, language arts, communication skills and mathematics.
9. The use of adults in the school and community as resources can enrich the program and the people themselves can be enriched and informed through their involvement with a program that reflects current science-related issues.
10. The quality of instruction depends largely on the school climate established by the building administrator and on the recognition of the teacher that teaching and learning science is important and can be interesting and satisfying.
11. Curriculum content should be based on what is known on children's interest, cognitive skills, etc. As the children learn to read, use research skills, etc., the curriculum content and the skills used should become more sophisticated.
12. Testing should measure the skills and/or content that is being taught. For example, if the lesson or lessons focus on the skill of classifying, then test items should evaluate the child's ability to classify.

APPENDIX B

REPORT OF THE WORKING GROUP ON MIDDLE SCHOOL (JUNIOR HIGH) GRADES 6-8

Status

Middle school teachers and students often feel an identity problem. Teachers must fluctuate between a nurturing elementary teacher and a content focusing high school instructor. State certification requirements across the nation reflect this problem with some states requiring an elementary certificate while others require a secondary certificate for this level. Middle schools frequently absorb teachers displaced because of declining enrollments. These people are often untrained to work effectively with young adolescents or in the content areas which they are asked to teach.

The student population manifests a wide range of maturity and developmental levels both physically and cognitively. It is not uncommon to find students functioning at the concrete, transitional or formal operational level in the same classroom. It should also be noted that the developmental level at which a particular student operates may vary depending on the assigned task. Personal awareness and questions about their surroundings often dominate students' thoughts and energies during these years.

Curriculum Recommendations

The middle school experience should enhance and further develop the basic skills of science introduced at the elementary school level. Academic growth and challenge should be developed through the exploration and application of scientific concepts.

A. Concrete experiences should be used to build on and further develop the basic skills of science introduced in the elementary grades.

B. Though the emphasis of the program should focus on concrete experiences, problem solving and logical reasoning experiences should be interwoven so that students can ask questions, manipulate variables, make generalizations and develop concepts.

C. The program should be exploratory in nature; an integrated or unified approach which covers earth, physical, life and health sciences during the year.

D. The program should interact with other disciplines. (Acid rain or nuclear power—science and social studies; data collecting or graphing—science and math.)

E. Career education in the areas of science and technology should be brought forth where appropriate.

F. Materials and topics should be developed in a differentiated manner in order to provide for the various ability levels within the grade.

G. The program should reflect decision making, so that students can evaluate personal and societal implications in regard to science and technology.

H. The use of new technology (microcomputers/calculators/cable television) should be integrated in the program so that students can experience their usefulness and evaluate the potential of these tools.

I. Use of local resources (museums, scientists, specialists) should be encouraged in order to extend the learning experience beyond the school walls and hours.

Professional Recommendations

A. Teachers must be certified in the areas of science for this level.

B. Opportunities are necessary for formal and informal ongoing staff development/training in the areas of science curriculum, adolescent behavior, classroom management and new technologies.

C. Support structures to assist teachers with state of the art ideas, resources or material.

APPENDIX C

REPORT OF THE WORKING GROUP ON BIOLOGY EDUCATION

Current school offerings in the biological sciences

Biology topics are part of the elementary school science curriculum from kindergarten through grade six. In the middle/junior high schools (grades 6, 7, 8 or 7, 8, 9) biology may be concentrated in a one-year life science course, or be included as a part of general science in a three-year program. In the senior high school, biology is a year-long course typically taught in grade 10, and enrolls approximately 75 percent of all students. Advanced biology is taught in many schools in grades 11 or 12. The course may be general biology of the advanced placement type, or more specialized courses in anatomy and physiology, marine biology, ecology or environmental science.

The present condition of biology education

Since biology is a part of elementary science it suffers the same neglect as all science in elementary schools. However, elementary school teachers are more likely to stress biology than the physical sciences whenever science is taught. The teaching emphasis at all grade levels is largely upon learning the names of plants and animals, their structural parts and the function of each. The student complaint is that "there are too many names and terms to learn." Certified teachers of biology are not in short supply. The teacher problems are those of missassignment within the schools, tenure and hiring practices, and the educational qualifications of teachers. Results from the national assessments of science and standard tests indicate little decline in student knowledge of biology over the past dozen years. The primary need for the revitalization of biology education is perceived to be a conceptual framework that is more in harmony with understanding oneself and which is supportive of the national and global welfare.

Recommendations to the NSB Commission

The biology group recommends that the educational context of the biological sciences be more sharply focused at different schooling levels. The curriculum in grades K-6 should emphasize a study of nature (plants, animals, humans—characteristics and diversity in the local environment) and biological phenomena (growth, reproduction, adaption, behavior, and other topics). In the life sciences of the middle/junior high school grades, the emphasis should be upon understanding oneself as a human being. This will require a broadening of the present subject matter to include concepts from anthropology, behavioral sciences, cultural geography, human physiology, and other human sciences. General biology in the high school (grade 10) should emphasize biological knowledge in a social/ecological context. The focus should be on biological concepts as they relate to human well-being and the common good. The advanced or second level course in high school biology should be taught in the context of a discipline emphasizing its structure, its modes of inquiry, its theoretical underpinnings, and its career opportunities.

All students would be expected to enroll in the biological offerings in the elementary and middle/junior high schools and in the general biology course of the senior high school. These courses should be regarded as a part of essential learning for responsible citizenship. The second-level biology courses of the senior high school would be elective. These courses should be designed primarily for students who wish to test a career interest in the biological sciences, or qualify for advanced placement in college.

A substantial fraction of the course work in the middle/junior high school life science course and in the general biology (10th grade) course should be organized in terms of biologically based personal or social problems and issues such as health, nutrition, environmental management, and human adaptation. Whatever the problem or issue that is studied, students would be expected to deal with the situation by utilizing valid scientific information. The resolution of problems and issues in a biosocial context usually involves value or ethical considerations; these are not to be ignored in the teaching of biology.

At all grade levels there should be an emphasis upon biological ways of thought. Students would be expected to acquire skills in making careful observations, collecting and analyzing data, thinking logically and critically, and making quantitative and qualitative interpretations. Quantitative procedures would be those characteristic of the experimental or empirical sciences. Qualitative procedures include decision making in real-life situations and emphasize holistic or systemic patterns of thinking with considerations of probability and values or ethics. The two patterns of thinking may be identified as 1) procedures associated with the acquisition of reliable knowledge—biological inquiry, and 2) procedures associated with the utilization of knowledge in personal and social contexts—decision making.

Equally important throughout schooling is the need for students to identify sources of reliable information in biology that they may tap long after formal education has ended. First steps in this direction can come by making use of museums, parks, zoos, television programs, qualified people in business and industry, public library assignments, and from other informal sources of information in the teaching of biology.

Students will need an understanding of basic biological concepts and principles if they are to make responsible use of what they are learning. These concepts and principles should be acquired in terms of the human organism with extensions to other forms of life. Among the basic concepts in the biological sciences that have personal and societal dimensions are: genetics, nutrition, evolution, behavior, reproduction, structure/function, disease, diversity, integration of life systems, life cycles, and energetics. The student should also acquire an understanding of how bioengineering and biotechnology are used to modify or sustain natural systems in organisms.

Special efforts should be made in the teaching of biological sciences at all grade levels to develop bridges or connections between biology and other school subjects such as mathematics, social studies and the physical sciences.

APPENDIX D

REPORT OF THE WORKING GROUP ON CHEMISTRY EDUCATION

Two general types of precollege chemistry instruction must be considered: (1) chemistry appropriate for all students, and (2) additional chemistry suitable for those intending study in areas requiring advanced preparation in this subject. All students, regardless of career goals, could follow a common chemistry syllabus (integrated or associated with other science areas), at least up to tenth grade. From this point we would recommend exploration of a two-track option—additional studies in chemistry for the general student (possibly integrated with physics), and more specialized chemistry study for those intending further work in this field. We recommend consideration of the Gardner/Yager 3-1-1 (or 3-2-2) sequencing of chemistry, biology, and physics study at the high school level for science-oriented students.

At all levels, the social and human relevance of chemistry should be emphasized. Problem-solving skills and application of scientific processes should be continually developed. Instruction should incorporate a proper selection and integration of topics from both descriptive chemistry and theoretical chemistry. Implications from recent research in cognitive psychology should be applied in establishing suitable criteria for this topic-sorting process.

Chemistry study should focus on observation and description of the behavior of common substances with the subsequent rationalization of what has been observed through development of simple models. Computer-based modelling of chemical systems (such as equilibrium systems, ideal and non-ideal gas behavior) should be explored, recognizing that such models should not be regarded as a substitute for direct student experience.

The number of topics covered in high school chemistry should be drastically reduced, with attention directed toward integration of remaining topics in two related ways: (1) integration of facts, concepts and principles within chemistry, and (2) integration of students' chemical knowledge with other sciences and with areas such as mathematics, technology, and the social sciences. High school chemistry must satisfy goals related to individual, societal and career-awareness concerns, rather than only addressing preparation for advanced study.

Barriers preventing implementation of new chemistry-teaching ideas include (1) The inherent resistance of textbook publishers to innovation or change; (2) A difference in the level of "respectability" associated by teachers with instruction in theoretically-oriented chemistry (high prestige) and applied (descriptive) chemistry (lower prestige), (3) The dynamics of the oft-cited principle that one tends to teach the way one was taught; (4) The general lack of suitable resource material to support the infusion of more applied, real-world examples into current courses.

Due to the effects of the "closed cycle" of university chemistry instruction necessarily influencing the nature of precollege chemistry teaching, a comprehensive "systems" analysis and attack must be made in addressing the problem of high school (and pre-high school) chemistry teaching. The cycling time may be as much as 16 years. Thus, relatively long-term solutions must ultimately be sought.

This report at least partially reflects recent efforts within the American Chemical Society (ACS) and the National Science Teachers Association (NSTA) concerning precollege chemistry teaching. This work includes many activities within ACS already reported to the Commission on Precollege Education (January 1983 meeting), deliberations currently in progress by the ACS Chemical Education Task Force, and NSTA's Report on the Desired State of High School Chemistry (1982).

APPENDIX E

REPORT OF THE WORKING GROUP ON PHYSICS EDUCATION

I. Why Should Precollege Students Study Physics?

An understanding of the basic principles of physics is a necessary foundation for most of the other sciences and for an understanding of many technological applications of science. Both the theoretical (testing hypotheses, deduction from observation, etc.) and the experimental techniques (measurement, error analysis, etc.) of physics have general application in science and technology. Even for those students who do not go on to major in science or engineering, physics provides important examples of how the physical world works and the kind of answers scientists can (and cannot) give to the important questions of life.

The basic coverage for a precollege student should include the traditional subject matter of physics: mechanics (especially force, motion, work, power, energy and the First Law of Thermodynamics), heat (including some kinetics of gases and the Second Law), electricity, magnetism, light and other electromagnetic radiation, atomic and nuclear structure and reactions. Precollege physics should be taught so as to demonstrate the general principles of seeking and knowing in science. The relevance of the understanding which physics provides to present and future problems and opportunities of our civilization should be constantly demonstrated and emphasized.

II. Use of Computers in the Physics Class

We welcome the use of computers in the physics classroom and laboratory if they are (1) used to increase the sophistication and satisfaction of problem solving; (2) taken advantage of in the laboratory for real time data collection, display, analysis, and storage; and/or (3) used to simulate real world situations that cannot easily be observed through direct demonstrations, laboratory experiments or field trips.

We are not excited about the use of computers as an expensive set of "flash cards" and believe that the replacement of direct labs or demonstration experiences by computer simulations is inconsistent with the evidence on how people learn from concrete *real world* experiences.

III. Structure of High School Physics Course

We recommend that physics, chemistry, and biology each be taught over a three year period. A possible scheme would be the following, which gives number of class periods/week.

	biology	*chemistry*	*physics*
10th grade	3	2	2
11th grade	2	3	2
12th grade	2	2	3

Such a scheme would allow students (1) to develop their understanding of science over a longer period of time; (2) to provide opportunities for integrating the three sciences; and (3) to allow for a spiral approach to some of the more complex topics.

APPENDIX F

REPORT OF THE WORKING GROUP ON ENGINEERING (TECHNOLOGY) EDUCATION

WHAT WE ALWAYS WANTED TO DO

Get the general public to make informed decisions in technology area.

Develop confidence in the use of technological systems (that technology can be a friendly aspect of life).

Prepare people for careers in technological industry.

Provide career information.

Provide a basis for personal decisions.

To help people overcome fear of change.

WHAT HAS CHANGED WHICH WILL HELP ACCOMPLISH THESE GOALS?

Technology which enables us to look at real problems using calculators and computers to do the "dirty math" enables us to use real data rather than canned problems).

Attitudes—specifically increased awareness of the environment.

Knowledge of how people learn.

WHAT ARE SOME THINGS WE HAD NOT EVEN DRREAMT OF DOING?

Introduce technology concepts into other areas: Trade-off, Feedback, Stability, Decision-making

Look at long term consequences of technological innovations.

WHAT IS IN THE WAY OF DOING WHAT WE WANT?

Reluctance to change.

Teacher perception of what is important.

Teacher shortage which results in additional numbers of teachers unprepared in the technology area.

Textbook publishers who need to "play it safe."

Teachers who teach the teachers.

Lack of understanding.

Standardized tests.

WHAT SHOULD WE TRY TO DO?

1. Gather and produce illustrative examples of ways to use the engineering concepts such as trade-off, feedback, and stability to help the public make informed decisions and prepare students for technology-based courses.

2. Encourage textbook publishers to include technology material in their texts in all areas of science and mathematics.
3. Encourage the development and use of special publications such as auto safety, fiber optics in communication, the connection between space exploration and the heart pacemaker.
4. Using knowledge gained from current publications of new technological developments, individual teachers and school systems should be encouraged to develop their own curriculum materials to fit the teaching of the new developments into their courses where appropriate.
5. A serious attempt should be made to introduce complete courses on science and technology into the school program for all students at the secondary level (specifically grade nine). These courses should not be limited to either the fast learners or the slow learners but should be directed at all citizens of a technologically-oriented society as part of the "basics."
6. Encourage discussion of the question of what should go out of the curriculum as more technology comes in, or if it is possible, to include technology material so that it so emphasizes the teaching of the existing course material so that little of what is existing needs to be eliminated.
7. More information regarding content of science-technology courses and potential careers in technology should be made available to school counselors through workshops. This will help them to guide students more effectively into appropriate courses and careers.
8. State education departments should be make a special effort to assure teachers that the inclusion of technological material in curriculum is not only acceptable but is actually desirable at all levels.
9. The developers and publishers of standardized tests should be encouraged to include technology oriented questions in specific discipline tests. For example, on a recent National Assessment test it was found that only 12 percent of the seventeen-year-olds knew that plastics come from petroleum and only 3 percent were aware that the U.S. mortality rate is worse than that of most western European countries.
10. No major developments of science-technology courses should be planned or funded without substantial planning and funding for broad-scale dissemination and implementation of these materials.
11. Since curricula, attitudes and points of view presented at the secondary school level tend to reflect the disciplines as modeled in the universities, and science teachers tend to teach as they were taught, it is important that new courses on technology be developed at the post-secondary level.

APPENDIX G

REPORT OF THE WORKING GROUP IN INFORMAL EDUCATION

All individuals can express or develop their interests in science, mathematics and technology through informal education experiences. Science centers, local scientific societies, industries, community groups, etc. can offer a wide variety of one time and ongoing experiences to extend the role of the school. The unique difference is that the individuals decide what they want to learn, when they want to learn it and to what levels of sophistication they want to learn it.

The goal is to develop intelligent "consumers" of science and technology. Individuals, who when faced with decisions as voters, value evidence over emotional appeals to help them reach decisions. They make decisions regarding their own health and life-style based on evidence and reasonable personal preferences, after taking into consideration short- and long-term risks and benefits of different decisions. This is contrasted to the individual who is "guided" only by advertising in health and life-style decision making. The goal is to provide information and experience of interest to individuals. This helps them see the value of evidence-based decision making as an effective approach to selecting from the many choices people have to make in regard to themselves and as involved members of society.

Organized centers for informal education in science, mathematics and technology such as science and technology centers where available can also serve a variety of additional functions such as the following:

1. Provide opportunities for career awareness and career exploration for young people through fairs, exposition career days, etc.
2. Provide major exhibitions, lectures and other presentations in science for the public so as to better inform the public and help them to develop a greater understanding and awareness of science and technology and its role in our society.
3. Take a leadership role in locally based teacher training and curriculum development utilizing their trained staffs as part of the necessary instructional and curriculum development leadership teams.

Needs of Superior Students:

One of the more serious problems in education in science, technology, and mathematics is to provide greater opportunities for the gifted, talented or otherwise superior student. These students may, in a short time, go beyond what their school and teachers can provide—apart from the teachers support and expression of interest.

Opportunities for such students are currently available in museums, science and technology centers, zoological parks, botanical gardens and a variety of similar situations. Additional personal and specialized in-depth experiences could be provided for such students by a wide variety of community and industrial organizations and groups. For example, the local Audubon Society or natural history museum could be encouraged to involve such students in their ongoing programs. Local industries could provide summer or school year research orientation and participation experiences. Mechanisms could be developed for helping parents to encourage youngsters with talents in these fields and special equipment such as computers could be made available to those who would not be likely to have them at home.

Apart from the actual experiences, the positive effect brought about by the student sharing his or her interests with concerned adults could be of enormous benefit in encouraging the individual.

APPENDIX H

REPORT OF THE WORKING GROUP ON K-12 CURRICULUM FOR SCIENCE EDUCATION

The group emphasized two of the Commission's goal areas: science literacy and science manpower. Relationships among these goals and the general outlines of a K-12 curriculum to meet the goals were addressed.

Any consideration of K-12 curriculum must be driven by an understanding of the demands put on education in a democracy that is part of a complex technological world. There is demand for scientific skills, attitudes, and knowledge. A technologically-oriented, democratic society cannot exist with large sections of its population ignorant of science and technology. Attitudes, skills, reasoning abilities and knowledge from science are prerequisite to a sense of control over human destiny on the part of the populace. Full science literacy involves the following four components:

—Ways of knowing: What do I know? What is the evidence?

—Actions/Applications: What do I infer? What are the options? Do I know how to take action?

—Consequences: Do I know what would happen?

—Values: Do I care? Do I value the outcome? Who does care?

The group agrees that science literacy is essential for all students. Science manpower requirements must be built upon a foundation of science literacy.

Even for students who take all available science courses, many existing K-12 science instruction programs are not adequate to produce science literacy. For the majority who take very little science, the situation is truly a national crisis.

The following is an illustrative K-12 sequence. While this is by no means the only way to achieve the goals of developing science literacy and science manpower, it serves to illustrate the nature and magnitude of the changes the group believes are needed.

K-6. An integrated, hands-on approach is needed, which focuses on the relationships between humans and the total environment. Problem-solving must be emphasized, including acquisition and analysis of data.

Grades 7-8. In grades 7-8, two primary emphases should be made. First, on human science, including human biology and personal health. Second, attention should be paid to development of quantitative skills in science. Computer-based experiences should be used appropriately to assist in development of quantitative skills that will be needed for more complex, applied problem-solving in grades 9-10. Skill in quantitative analysis of data, application of probability and estimating skills are examples.

Grades 9-10. A two-year sequence, required for ALL students, would address Science, Technology and Society. This course emphasizes problem-solving and scientific reasoning as applied to real-world problems. It integrates knowledge and methods from physics, biology, earth science, and chemistry as well as applied mathematics. Examples of the kinds of phenomena and science addressed are included in the report from the technology subgroup.

Rationale for placement of this sequence at the 9-10 grade level is that the students need to have acquired certain developmental math and problem-solving skills which are prerequisite to the complex kinds of problem-solving tasks required in this course. This is a much higher level kind of course than is generally recognized as a "general science" course for non-science students.

Grades 11-12. One and two semester courses in physics, biology, chemistry and earth sciences are provided at this level for students who wish to go on to further academic study in science-related careers. These are not Advanced Placement courses and are not meant to replicate college-level courses. These courses do build upon and assume as prerequisites the skills and knowledge in the various science disciplines that students will acquire in the Science, Technology and Society course in grades 9-10.

Long Range vs. Short Range. The implications for implementation of a plan such as the one outlined above are major. Science teaching staff would double from the existing staff. Extensive curriculum development and teacher training is required. Full implementation nationwide would probably take about 15 years. However, phases of implementation are possible. Initially, the Science, Technology and Society course would be only one year on a required basis for all students. The second year would be optional or elective while further materials, curricula and staff are being developed.

APPENDIX I

REPORT OF THE WORKING GROUP ON INTEGRATING MATH, SCIENCE, TECHNOLOGY

1. When possible, science-technology situations should be used to introduce mathematics topics at all grade levels.
2. Mathematics courses in grades 7, 8 and 9 should introduce (if it hasn't been done previously) and stress probability, proportional reasoning and intelligent estimating.
   Example:
   Is your ten speed bike really 10 speeds?
   Requires—ratios of teeth on gears.
   Speed ratio is verse to force ratio.
   Distance traveled by foot requires measurements which have limits of accuracy and therefore can be used to introduce concept of significant figures when calculations on the calculator give the ratio in 10 "significant" figures.
3. An integrated science-technology course should be the basic science course at grade nine.
   Examples:
   The use of technological systems for earthquake prediction should be part of the earth science component of grade 9 science.
   The operation of the clock thermostat should be used to introduce feedback and control and its value in energy conservation.

Smoke Detector

The examination of the ionization smoke detector for radioactivity and the measurement of that radio-activity at various distances from the source followed by the graphing of the data will help to develop the relationship of intensity of radiation with distance. Comparison of the radiation received 30 inches from the smoke detector by standing under it for 8 hours/day, 365 days per year and that received by a person during one dental x-ray is interesting. Deciding the relative value of knowing that you have a decayed tooth compared to saving your life in case of a home fire is a useful outcome of such.

Acid Rain

If we look at the effect of acid rain on buildings and monuments we learn that while calcium carbonate (marble) is essentially insoluable in water, calcium sulfate and calcium nitrate are very soluble. In the examination of Tables of Solubility we learn that barium sulfate and barium nitrate are not nearly as soluble. If we could replace the calcium ions on the surface of marble with barium the new marble will withstand the ravages of acid rain while developing systems for eliminating acid rain. A laboratory activity capable of being done by grade 9 students will demonstrate that this is possible.

Measurement of the deterioration of gravestones in V.A. cemeteries will also give us data on how the rate of decay has increased over the past 200 years compared to previous periods of time.

"There is an aparent need in technology education for a leadership and coordination function at the national level. The activities recommended earlier are likely to have little impact unless they fit logically into a coordinated group effort of those supporting technology education. We recommend the formation of a national center for leadership in technology/society education. Such a center would probably need to be supported for a number of years and would serve as a continuing stimulus for coordinated activity. It should serve as a clearinghouse for strategies, information, and ideas, and as a proactive coordinator of research, development, and dissemination activities. One of the first activities of such a center should be a thorough study of resources available in technology/society education. Resources to be sought and organized would include funding sources; existing support groups, institutions, agencies, and individuals who support technology/society education; and materials and techniques which have been developed to aid technology/society education. Subsequent activities would then be designed to coordinate these resources into a viable national effort. We are convinced that such an effort is crucial at this point in our country's development."[1]

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[1] From "What Research Says to the Science Teacher," published by NSTA.

APPENDIX J

REPORT OF THE WORKING GROUP ON TECHNOLOGY IN TEACHING

Science educators are moving rapidly toward the increased use of technology and a recognition of new roles for technology in science and science teaching. Although we examined the potential contributions of several technologies such as computers, educational/instructional television, videodiscs, teleconferencing, computer-based conference, and interactive cable, we chose to discuss some recommendations and reservations regarding the use of the microcomputer specifically. This can serve as an example of the promise and problems associated with the use of such new technologies in science education.

The revolution in microelectronics and telecommunications must be used in ways which contribute to the continuing evolution and improvement of science and technology education. A short burst of enthusiasm, even if well placed, will not be of long-term service to students or to this nation. Within microcomputing itself, it is all too easy to act as if the equipment and its casual use represent the new panacea for science and technology education—and then subsequently suffer the disillusion and depression which necessarily follow when such lofty expectations are not met. Thus the following recommendations are accompanied by reservations and cautions needed in a time of rapidly changing options in instructional technology.

Computer Applications of Particular Importance in Science and Technology Education:

Recommendations

1. *As a tool for computation*, have the computer carry out, for example, a statistical analysis which is otherwise too time-consuming or awkward. But students should understand how such mathematics could be done manually, i.e., "what's going on inside the black box." On the other hand, in standard computation such as solving simultaneous equations the computer can be just a "black box."

2. *As a tool for interfacing with laboratory equipment*. Have the computer assist with gathering bench data, displaying it on screen, printer, or plotter, and perhaps analyzing it. But students still need to get firsthand experience, e.g., calibrate and test the equipment, or even do the experiment once without automation, followed by exploration of the variables with further computer interfacing.
3. *As a tool for processing information*. Having the computer organize, graph, and analyze data, or search a database for information. Still students must have enough experience with manipulation of data by hand to understand what is going on inside the computer.
4. *As a tool for creating and testing models*. A computer-generated model can serve as an aid to description, concept-clarification, and problem solving, even though it is not a totally faithful representation of the 'real' system being modelled. Striving for a close match with reality, in fact, is not necessarily appropriate. Too much fidelity in a simulation detracts from its educational value and gives a false impression of the role of simulation. Appropriate abstraction in the model calls attention to important variables and relationships. It's far better to have students examine, criticize, and modify a model than to experience a simulation and mistake it for a totally accurate representation of reality.
5. *As a tool for describing processes, procedures, and algorithms*. Developing computer programs involves basic problem-solving strategies (understanding and defining the problem, identifying subproblems, seeking solutions, debugging, etc.). The computer offers an environment where new ways of representing complex ideas can be explored. These opportunities go far beyond programming languages such as BASIC, Pascal, and Ada. Changes (qualitative improvements) in software and applications packages are making computer descriptions of phenomena and systems in science and technology more accessible to students.

Additional Considerations and Reservations in Computer Use

1. Computers are important, exciting, and fun. As a result, there is a current tendency to ignore other instructional technologies. Some may appear too narrow in scope or too expensive presently (e.g., intelligent videodisc, computer-based conferencing, interactive cable), but will be economical within five or ten years. Some technologies which may no longer appear 'exciting' (e.g., video tape and computer-assisted instruction) can still help supplement instruction in schools where available teachers lack background in science and science education.
2. Potential computer users should be cautioned not to reject the concept of computer-aided instruction because of shortcomings in present software and equipment. The most certain prediction within the computer field is *change*, and improvements necessary for success in business and consumer markets will benefit education as well.
3. The attitude of science teachers toward student computer skills should be similar to current attitudes toward student mathematical skills. We can establish some broad expectations regarding the computer skills science students should have, and then be ready to provide instruction or assistance as necessary to support computer uses peculiar to science and technology education. Science teachers' responsibility toward computer education is no greater (nor less!) than their current responsibility toward mathematics education.
4. The problem of access is sufficiently serious that those schools (and homes?) without computers may need outside assistance to provide equal access. It may become necessary to carry out a Government mandate to assure student access to appropriate computing.
5. Appropriate instructional technology must be used within preservice and inservice teacher programs to demonstrate its proper uses as a teaching tool in science and technology education, and to minimize the possibilities of misuse of the technology in inappropriate settings. (Any computer program that can be replaced by a teacher probably should.)

Planning and Implementation

Rational use of the new technologies in teaching must be based on careful analysis and planning within three related areas:

People. A national program must include assistance, support, and education for teachers, administrators, and others making use of new technologies in teaching and learning activities.

Materials. A national program must provide incentives for development of quality materials and software necessary to provide effective instruction through tools such as those listed earlier in this report (computation, instrumentation, modeling, etc.). These tools must be put in the hands of students by teachers possessing appropriate background in the proper use of these materials.

Ideas. A national program must invest in research and long-term development, creating new capabilities and anticipating difficulties in the uses of instructional technology. We need to understand much more about learning, learner-machine interactions, and effective strategies for teaching with, about, and through computers.

Technology must be taken beyond the fascinating equipment capable of transmitting, storing, processing, and displaying information. For effective use of education, greater attention is needed to the development of software and materials which can define new computer-based environments for learning. Both systematic and creative approaches are needed to develop, refine, and validate such instructional material.

Within video technology, we can already identify impressive productions which exploit the medium to present important science/technology concepts and involve the viewer in considering their consequences and applications. Video sequences can be found which motivate, inform, and challenge students, and then lead to classroom discussions, field trips, or laboratory work involving students in important learning tasks. Analogous uses of newer technologies in enhancing instruction must be sought and developed, recognizing technology's potentially valuable role as a suplement to (rather than a replacement for) other successful teaching strategies.

Educational planners and decision makers (such as Commission members) should obtain a microcomputer typical of current technology to use at home, plus a library of the best available applications programs and supporting materials. In a familiar setting, they should have the opportunity to try the computer and software with family and friends of various ages. They should also participate in a computer-based conference or electronic bulletin board with educators exchanging information and advice on new technology. Of course they should also observe similar technology being used in a school and talk to students and teachers about their experiences and impressions.

APPENDIX K

REPORT OF THE WORKING GROUP ON CURRICULUM DEVELOPMENT

In any science curriculum development it is necessary to provide that science which is basic to modern technological society. Great progress has been made in the development of rigorous courses in the science disciplines taught in secondary schools. Changes in those courses need to be made to bring them up to date with the latest scientific and technological developments. Additional curriculum materials which bear even more on ongoing developments in the sciences and technology and interface with present and future personal and societal needs and career awareness, also need to be developed. Many of these changes will be in the context in which concepts, principles, generalizations or theories are taught.

While there is essential agreement on which concepts, principles, generalizations and theories should be taught, the context and emphasis will in some cases vary from region to region or even within regions. It is important, therefore, that local groups as well as national groups be involved in revising and developing curriculum in the sciences. In order to meet local needs as well as provide curriculum which does in fact speak to all of that which is basic to modern technological society, it is necessary to have a viable system for developing curriculum.

1. At the national level a set of non-prescriptive guidelines accompanied by a large set of illustrative examples will be developed. This development would take place at a number of regional centers which would be commissioned for that purpose.

   Staff at such a center would include personnel with established credentials in one or more of the following areas; subject matter, research in science education, curriculum development, teacher education, teaching science at the various levels, and curriculum implementation.

2. In order to have the optimum opportunity for infusing the curriculum into the classroom, it is important that the local group indicate a commitment to trial and implementation of the curriculum materials which are developed by the local groups.

These local groups, which would be organized in a variety of ways, would be asked to write proposals explaining among other things the needs as they see them and the system for implementation. They would meet during the summer for a period of six to eight weeks with resource people either at one of the regional centers or at a local center which has been designated for curriculum development. The science teachers would be paid a sum which is equal to or greater than their academic salary for the same period of time for this development.

During the ensuing year some of these people would be assigned and paid for the additional responsibility of continuing curriculum developing at the center and assisting teachers at the local level with the implementation of the new materials.

This system will encourage and reward outstanding teachers and serve as a basis of re-education of all who are involved.

APPENDIX L

REPORT OF THE WORKING GROUP ON TEACHER PREPARATION—ELEMENTARY K-8

All teachers must be qualified and certified to teach science; K-3 Science Specialist monitors and assists the regular classroom teacher who teaches science.

4-6 Science Specialist in one of four modes:

1. Trained Science Specialist in each classroom.
2. Specialist trades with other teacher. (science—social studies switch).
3. Moving Science Specialist to each class.
4. Moving classes to Science Specialist

7-8 Trained Science Specialist in each science class. Teacher education:

1. Strong science courses—lab based.
2. Early opportunity for observing and participating in science teaching. Don't wait till the last year.
3. Child development: Psychology of the child through adolescence.
4. Training in the use of technology.
5. Method courses in the application of knowledge on child and adolescent development to science education.

Elementary Teacher Preparation K-8
Characteristics of Pre-school/In-service

1. Hands-on experiences.
2. Activities that enhance questioning.
3. Developing creative skills.
4. Developing problem-solving skills.
5. Understanding the use of technology.
6. Understanding the emerging adolescent.

Summary

Teachers should understand, use, and apply the skills in science as stated. (Skills being defined as concepts and process interwoven.) Pre-service education should include training in the practicalities; e.g.

1. Bulletin boards.
2. Learning centers.
3. Managing equipment: using, storing, repairing, and managing students using the equipment.
4. Use of resources: Development of professionalism through an awareness of professional organizations and educational publications and how to gain access to them.

In-service education should include participation in curriculum planning and/or writing curriculum materials by teachers.

Long Range Plans

1. Create a study on how one can train an elementary teacher in 120 semester hours, including the necessary competencies in science, mathematics, language arts, social studies, etc. as well as psychology and methods courses. Is it possible to do all of this well or not? What school background for the prospective elementary teacher would have to be presupposed?

Short Range Plans

1. Look at the characteristics of exemplary programs for the preparation of K-8 teachers such as those identified by "Search for Excellence."
2. All teachers should have some training on the use of calculators/computers.
3. All teachers should be aware enough of research in science education and be familiar enough with education technology to be comfortable in carrying out action research in the classroom.
4. In-service education of science teachers must be designed so that required professional paid continuing education will be maintained for the next couple of decades.
5. Such education clearly separates into two clienteles:
   (1) Those who must be trained to be qualified to teach science- or present science teachers who are qualifying to teach new subjects.
   (2) Those who are qualified and are updating their qualifications.

APPENDIX M

REPORT OF THE WORKING GROUP ON TEACHER PREPARATION GRADES 6-12

Some type of differential pay in money, time, or other form of remuneration needs to be adopted in order to attract and hold qualified science and math teachers. We strongly recommend that a subcommittee meet after these deliberations with leadership from the AFT and NEA to discuss creative ways to approach the subject of differential pay.

A few centers across the country should be identified or created as models of pilot programs of exemplary science education at all levels. These centers should include university personnel in the content areas, science curriculum experts, science educators, learning theorists, communication specialists, master teachers, exemplary school districts, etc. Such centers could eventually serve as a nucleus for expanded teacher training programs.

It is strongly recommended that two levels of inservice science education programs be immediately implemented:

(1) to update teachers who originally received adequate training but are now lacking in new content knowledge, use of new technology, and use of methodology in relating science curriculum to the community,

(2) to train teachers who have little or no preparation in science content or science teaching strategies in the area(s) to which they have been assigned.

It is imperative that a permanent national inservice science education program be put into place as a long term investment to continually update and improve science education. The science curriculum should be revised to better relate science with the community and other subject areas. Teachers must be continually trained and retrained to meet the needs of students living in a changing technological world.

Support for science curriculum change and development as well as teacher training to manifest this change is urgently required.

APPENDIX N

REPORT OF THE WORKING GROUP ON SUPPORT FOR IMPLEMENTATION AND CHANGE

Preamble

This report is prepared under the assumption that federal funds exist both in 1983-1984 and in future years for the initiatives and program recommendations likely to emerge from National Science Board Commission reports. We are particularly concerned that those funds be disbursed in ways which address the concerns of highest priority, and not on the basis of political or other irrelevant interests.

Recommendations

1. Support should be provided for the creation and operation of a National Center for Science Education. Such a Center would have the advantage of concentrating talent and resources, without the constraints and limitations found in schools or school districts. Thus, innovations in scope, sequence, and content, as well as apparatus and resources could be all brought to bear on the problems of science education in one Center. The Center could include a materials development center and research library, along with K-12 demonstration and research school, in which the best possible teachers, facilities, equipment, etc. could be used with a representative group of students.

   Such a Center could be supported by a mixture of public and private funds. The private sector could also participate by contributing state-of-the-art electronics, computers, and other material and equipment. This Center could operate under the oversight of a "Joint Council" of the type being proposed by the National Science Teachers Association (modeled after the Joint Council on Economic Education). The National Center could serve as a national repository for advice and information on science education.

2. Pertinent data on all aspects of science education should be collected annually by the Science Resources Studies Group of the National Science Foundation (NSF). These data should be analyzed and their highlights made public. The data collection should be maintained and results stored in some permanent fashion so that the important information they contain is continuously available.

3. There was a strong feeling that the National Science Foundation, which supports through its basic research program, the creation of knowledge, and which has strong links with scientists and science education personnel in universities, colleges, and industry, is the agency through which support for science education programs should be funded. There was also much concern that the FY 1983 appropriation be allocated with a proper balance over the areas of priority identified by this meeting and by the National Science Board Commission. Thus, we recommend that the following resolution, endorsed by this meeting, be communicated to appropriated officials of the NSF and elsewhere by the NSB Commission:

   > Be it resolved that this "Conference on Goals for Science and Technology Education" calls for immediate approval of guidelines for the $15 million of NSF Science Education funds for FY 1983. These guidelines should insure a proper balance among science education research and development, computer utilization, public awareness of science, and teacher institutes, with at least half of the funds designated for the support of teacher institutes. Furthermore, we strongly recommend that most future support for research and development in science education, as well as support for teacher training, be provided through the National Science Foundation.

4. Within each state an individual or group should be identified to provide leadership for the improvement of mathematics, science and technology education. In most instances, the State Science Supervisor or the equivalent would provide this leadership. Funding should be made available for the necessary statewide needs assessment, resource identification and data collection. This joint state group could work with the Joint Council proposed by NSTA as described in (5) below.

5. An important feature of the Joint Council being proposed by NSTA is the state structure which is also loosely modeled after the Joint Council on Economic Education.

   The agency identified in (4) above would be encouraged to set up a joint state organization, with representation from science, education, business, industry and labor. Such an organization would provide state-level leadership and enter into cooperative efforts to improve precollege education in mathematics, science and technology. These joint state groups would be represented on the Joint Council.

6. NSF FY 1983 appropriated funds for science education should be allocated for first-phase support of high priority initiatives identified by this "Conference on Goals for Science and Technology Education." In this way, many of the efforts which are needed could begin as early as Fall 1983.

7. Cost sharing and matching requirements of NSF guidelines should be small and flexible. Need and merit should be criteria that are included in funding considerations.

8. There were many excellent materials development projects over the past ten years

which did not include a dissemination component. Some of these efforts resulted in production of fragmented sets of materials; others produced entire sets. There are other sources of such materials. Funding should be provided to examine, evaluate, revise where appropriate, complete, and disseminate those materials that address goals appropriate to the 80's.

9. There must be a careful balance in support of national materials development efforts and the local efforts to select, assemble, adapt, and sequence high quality curricula. There must be local training and familiarization. There also must be strong involvement of teachers in national efforts. The Joint Council would provide a national forum for discussion and coordination of the many materials development efforts that will arise.

APPENDIX O

REPORT OF THE WORKING GROUP ON SCIENCE EDUCATION AND THE PHYSICALLY DISABLED INDIVIDUAL

The educational emphasis that is necessary for the disabled is one of "Enabling the Disabled rather than Capping the Handicapped."

Therefore, for disabled individuals just like their nondisabled peers, it is necessary to transmit and develop the information and understanding that is necessary for individuals to become independent, contributing members of society. In addition, and more important, it is necessary to help individuals, disabled or not, *to learn how to learn*. Then whether it be in the world of work or as particpating citizens in our democracy, individuals will be able to adapt to changes, process and analyze new information, and make intelligent decisions based on the evidence.

Our whole society is becoming more dependent on science and technology every day. We expect our citizenry to make a wide variety of science and technology-based decisions in the world of work and in life generally. Therefore, science and related fields have become extremely important in the education experience of all learners. For disabled learners, science instruction starting at an early age and continuing throughout their school career takes on added importance for the following reasons:

1. Science emphasizes hands-on experience and exploration of the environment, both physical and biological. It can help to fill some of the experimental gaps in the background of many physically disabled individuals. Whether these gaps have evolved because of extensive hospital stays, overprotectiveness of schools or parents, or a variety of other reasons, these hands-on experiences are essential in developing knowledge and understanding of one's environment and one's personal relationship to it. Such understanding is extremely important in helping to develop the individual's independence and overall positive self-image.
2. Recent scientific and technological advances have provided the tools (computers, talking calculators, control systems, versabraille hook-ups to computers, TTY telephone systems, etc.), which can help to mitigate the limitations imposed by a physical disability. This can help enable disabled individuals to be independent contributing members of society. In order to effectively use these technological devices, disabled individuals need first to know about them. Also helpful is a variety of experiences exploring variables, using equipment and materials, machines and related devices. Many of these technological devices involve organizing and inputting information. Science instruction with its emphasis on making observations, collecting and organizing evidence, and coming to conclusions can be significantly helpful in developing the individual's psychological and manipulative readiness for using technological devices.
3. Job opportunities in the future for all individuals will require greater knowledge and understanding of technological devices and how they work. The computer will become an important part of many jobs in the future. Because of technological advances in alternate ways for individuals to use computers, many of these jobs are available even to the seriously disabled if they have the necessary background and training and perhaps more importantly, self-confidence to seek the position. Early experience-based science education can help disabled individuals to develop the skills and attitudes necessary to effec-

tively take their place in the world of work as independent contributing members of society.

If concern for the physicaly disabled sounds too altruistic to some in times when "hard economic decisions" are necessary, it is important to note that an independent self-reliant disabled individual can be a full contributing member of the society. The alternative is the totally dependent individual who has to be cared for indefinitely at costs per year far in excess of the entire cost to provide an effective science program. Science education cannot solve all problems but it can make a significant contribution. From humane and economic points of view, we can do no less than provide disabled individuals and their peers with the best possible science program. To do less is cheating disabled individuals and ourselves.

APPENDIX P

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APPENDIX Q

AGENDA

Conference on Goals for Science and Technology Education, K-12
Washington, D.C. March 11-13, 1983

Friday, March 11

Friday, March 11

8:30 p.m.	Plenary Session • Statements and discussion about the purpose of the conference • Brief reports on recent studies and reports on the status and needs of science and technology education and on learning/teaching methods

Saturday, March 12

9:00 a.m.	Plenary Session • Discussion of the agenda • Discussion about type of information needed from groups
9:30 a.m.	Group Meetings: Elementary School Science, Biology, Chemistry, Physics, Engineering
2:00 p.m.	Plenary Session • Reports from groups • Organization of afternoon groups on other science areas, overlapping areas, special emphasis for different students, etc.
3:30 p.m.	Group Meetings

Sunday, March 13

9:00 a.m.	Plenary Session • Reports from groups • Discussion about educational feasibility of suggested programs and teaching problems
11:00 a.m.	Groups meet to draft reports
2:00 p.m.	Final Plenary Session • Decision on conference recommendations • Discussion about conference report format
3:00 p.m.	Group report-writing until departure times

APPENDIX R

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3 INTEGRATING CONCEPTS OF ENGINEERING AND SCIENCE INTO INSTRUCTION IN GRADE LEVELS K-12

Report from an *Ad Hoc* Subcommittee of the NSF Engineering Advisory Committee
Prepared by J. H. Mulligan, Jr., ***University of California, Irvine***

EXECUTIVE SUMMARY AND CONCLUSIONS

At its meeting in December, 1982, the Advisory Committee for Engineering* of the National Science Foundation discussed the work of the Commission on Precollege Education in Mathematics, Science, and Technology as reported in documents made available by the staff of the Commission (primarily, *Today's Problems, Tomorrow's Crises).* The Advisory Committee benefited from attendance at the meeting of Commission Co-Chair Dr. Cecily C. Selby and staff member Ms. Mary Kohlerman. Two recommendations resulted from the meeting: (1) instruction in science and mathematics throughout grade levels K-12 should include stress on applications to practical problems, and (2) the instruction in these grade levels should include concepts of engineering, including synthesis and applications, selected as appropriate to each grade level. Dr. Selby extended an invitation to the Advisory Committee to provide comments to the Commission dealing with these recommendations. This document responds to that invitation.

This report is the work of an *ad hoc* subcommittee of the Advisory Committee consisting of Richard H. Bolt, Richard J. Goldstein, J. H. Mulligan, Jr., and Klaus D. Timmerhaus, under the chairmanship of Dr. Mulligan. Dr. Jack Sanderson, Assistant Director for Engineering, National Science Foundation, met with the subcommittee, and he and Dr. Carl W. Hall, Deputy Assistant Director for Engineering, contributed to the development of the report. All members of the Advisory Committee were given an opportunity to comment on a draft of the report, and comments received as a result have been incorporated in this document.

The principal conclusion of the report is that in recommending changes in mathematics, science, and technology education in levels K-12, the Commission should give serious consideration to the introduction of engineering concepts and their integration in mathematics and science material, including practical applications, within courses in many subjects throughout the curriculum. This action is necessary to ensure that all graduates completing instruction through grade 12 achieve general technical literacy, as well as to improve the precollege preparation of students intending to pursue professional careers in mathematics, science, or engineering. Separate courses should not be used to present the material recommended; instead, the concepts and applications should be introduced by modification of existing courses.

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*See Attachment 1 for membership.

Curriculum materials, including laboratory exercises, will have to be prepared to make the recommended transition feasible, and various forms of teacher training also will be necessary. Case studies, including design and synthesis, analogous to those developed for engineering undergraduates should be developed for the high school level. Summer programs which enable mathematics and science teachers to interact as participants with research or design groups in universities and industry should be instituted. The engineering profession, acting through its professional societies and the engineering colleges and universities could assist materially in the transition process, including facilitating arrangements for cooperating with industry.

INTRODUCTION

The recent report of the National Commission on Excellence in Education has emphasized the decline in quality of precollege education and has offered suggestions to correct the condition. We are familiar with the continuing movement of U.S. precollege education away from mathematics, science and technology. This trend has been emphasized repeatedly, particularly when comparisons are made between the precollege education of students in the U.S. and that of students in Japan, West Germany, and Russia. This trend has been underway for some time and comes as a result of apparent disinterest on the part of parents and the preoccupation of the public with other more personal needs. For the most part, until recently, the U.S. public has seemed quite unconcerned about the impact of technical illiteracy, because such deficiencies do not appear to have adversely affected their personal lives. In fact, however, there are far-reaching consequences of this illiteracy, not the least of which is the inability to design and manufacture high technology products that are competitive here and abroad with those products of foreign nations. Recession and unemployment result from many causes; a lack of proficiency in capitalizing on developments in technology is certainly one of the major contributors to a depressed economic condition.

If this is the present situation and the public in general shows little interest in this aspect of precollege education in the U.S., why should the engineering profession be concerned? For one reason, our culture is increasingly technology based, so the engineering profession should undertake a responsibility to deal with the need for educational improvement. Perhaps a more compelling reason is that our country has entered a most critical period in which we find ourselves faced with growing competition from other developed countries, which have for some time recognized that their future survival would depend on the maximum utilization of their human resources. If the U.S. is to retain a leadership position, or is even to keep pace with these countries, it will need to maximize its development and use of human abilities. The extent of such development in the U.S. will be highly dependent upon constructive changes that can be effected to strengthen, to rekindle interest in and to provide greater relevance in precollege and college education during the coming decade.

We also find a philosophical reason for the need to effect a change in the present precollege education. Our society has long taken the view that every youngster should have extensive study in the English language because of the need to communicate and that a certain amount of history should be learned in order to provide a better understanding of Western civilization. Similar arguments are made to justify the study of liberal arts, music, and other subjects. None of these courses is studied primarily to prepare the student to enter the teaching profession, or to become an historian, or a musician; rather, the subjects are studied to help all students develop a better understanding of the world in which we live and the society to which the student will contribute as an adult.

The emergence of high technology in the past generation has added another dimension of knowledge needed for dealing with world affairs. It is just as important for the young student to be able to understand and appreciate what science and technology are and what they can and cannot do for society as it has been to study the other areas which society has come to regard as essential in the education of young people. Scientific and technological literacy is needed to understand many of the issues, including those on local, national, and international levels, on which our citizens will vote or express their opinions in other ways.

From this standpoint, what changes need to be made in precollege education? Basically, we must redefine the goals of precollege education. If the educational process is to provide young people with the background needed to understand the world in which we live, then we must recognize that science *and* technology are integral parts of today's world, and that these subjects are essential elements for attention throughout the K-12 curriculum. This is particularly important for those young people whose formal education ends at grade 12. This need *does not* call for the addition of special new courses. Rather, it calls for a careful incorporation of the concepts of mathematics and science and their practical application into courses presently available in many subjects, particularly courses such as social sciences and history. Even mathematics instruction can be made more interesting and useful by incorporating various scientific and technological concepts within the course presentations. What is even more important is to educate young students in the scientific and technological approach to the solution of everyday problems. It must be demonstrated that the quantitative approach to reasoning is not only logical, but is also much more effective than simple intuition or feeling in dealing with matters where analytical decisionmaking is appropriate.

The Commission has expressed the view that K-12 instruction in mathematics, science, and technology needs to be strengthened. The Advisory Committee for Engineering agrees. However, the Committee believes that the educational process must include an additional element: a bridge from science and mathematics to the development and use of technology. This includes the integration of engineering concepts in the instruction of science and mathematics. The *utilization* of mathematics and science in the solution of practical problems must be stressed, and the nature of the engineering process and engineering concepts must be taught. An essential element of engineering, one that is absent from science and mathematics, is the process of synthesis or design. Engineering draws substantially from mathematics and science and is highly dependent on these disciplines in the design process. It is the design process, however, that ultimately produces technological change, and this change is governed in turn by economic and social considerations. Attention to this fact of life must be included in the formal educational process and not left to chance as an element of one's development as a citizen.

An important element of the educational experience in grade levels K-12 is the role that technology plays in our society, including the influence of the engineering process in the development and utilization of technology. It is the thesis of this report that instruction stressing the utilization of mathematics and science and the nature of engineering should pervade instruction in grade levels K-12.

Engineering education at the college level draws heavily on mathematics, chemistry, physics, biology, and the social sciences including economics. From a purely parochial view, therefore, substantial improvement in the K-12 mathematics and science instruction and introduction of engineering methods and concepts would be quite desirable, as it would have a pronounced effect on the quality of the preparation of those aiming at professional careers in science and engineering. But a second and more compelling reason for making the suggested changes in precollege education is the importance to the nation of achieving in the next generation a substantial increase in the technical literacy of its citizens.

CURRICULUM CONTENT

At the outset, we note that the Advisory Committee *does not* propose separate courses to deal with the integrative process. The engineering concepts to be presented and the details of their application should be included as natural elements of the work in mathematics, science, social studies, and even the arts. We recognize the important need for improvement in the quality and quantity of precollege courses identified as mathematics, biology, chemistry, physics, and the like; this need continues to be addressed by other groups. But this report deals with a different need: the need to integrate science and engineering concepts, including their application, into courses on many subjects throughout the curriculum. Of course, in addition to the substantial benefit derived by all citizens, the integration of science and engineering concepts will provide a stimulus for mathematics and social science studies and, hopefully, develop a curiosity among young people which will tend to encourage a greater involvement in these areas.

Social Studies

With regard to social studies, attention should be directed, to the degree appropriate for each grade level, to questions of how people—as individuals and their aggregation into nations—contribute to technological change and how people are affected by it. With regard to the broad subject of technological change, carefully selected examples can illustrate the forces that drive the change, the details of how the change is accomplished, and the effects on society—both good and bad—that are directly attributable to the change.

Synthesis and Design

Synthesis or design is generally absent from the fields of mathematics and science. Consequently, one will need to introduce additional topics which deal with the utilization of mathematics and science and the application of these subjects to the systematic synthesis of products and processes. Field trips, "hands-on" demonstrations, and special presentations by individuals in industry directly involved in creating high technology products are envisioned as essential elements of the curriculum dealing with synthesis. In the incorporation of these activities as part of the educational experience, special emphasis should be given to the interplay among science, engineering, and economics in the design and manufacturing processes.

Mathematics, Science, and Their Application

The technical material used as a vehicle for teaching mathematics, science and engineering, from an integrated point of view, could assume several distinct forms, depending on grade level. Fairly detailed considerations of case studies in the history of science and technology provide fertile sources for interesting illustrations. Experiments by such scientists as Torricelli, Galileo, Newton, Boyle, Dalton, and others demonstrating quantitative and unchanging relations in physics and chemistry could be introduced into the curriculum at an early stage, with emphasis on the mathematical expressions involved and some practical embodiments of the principles. Simple experiments in electricity, heat transfer, and mechanics, such as the properties of the pendulum, for example, could be introduced early in the curriculum. These could be followed by discussion of simple machines. For example, the study of James Watt's contributions to steam power would be interesting and rewarding. The design principle of the Newcomen engine, which provided the basis for the earliest internal combustion engines, is simplicity itself. Watt's use of the concepts of sensible and latent heat in the condenser design, poppet valves, planetary gears, and other machine elements provide numerous examples of scientific thinking which, along with synthesis, provided important practical benefits. Another prolific source of interesting applications of scientific principles is the taming of fire for space heating. Beginning with Franklin's notions about heat transfer, which led him to restrict the air flow up the chimney, one could introduce Benjamin Thompson's (Count Rumford's) many contributions, particularly the role of radiation and reradiation. The shape of today's fireplace and the design of woodstoves can be traced directly to the contributions of these two.

Identification of the connections between the various scientific and technological milestones with changes in the style of living of the people and the development of their nations constitutes a good example of the integration process which is being recommended.

Broad Engineering Concepts

Subjects that are introduced in the text, *The Man-Made World*, constitute an excellent pool of curriculum topics for the upper half of the K-12 instructional spectrum. With the recognition that the level of discussion must be selected to be appropriate to the various grade levels, topics such as the concept of a system, modeling, feedback, stability, optimization, analytical decision making, and complex problem solving would be rich in curriculum possibilities. In many instances, there would be direct and easily obtainable illustrative examples in the world and localities in which the students live.

Case Studies in Design

Grade levels 9–12 could include detailed technical descriptions and case histories of design examples associated with products, processes, and systems that are familiar elements of our daily life. Social studies courses could deal with the impact locally, nationally, and internationally of such technological devices and systems as electronic calculators, robotics, energy conversion devices, computer aided manufacturing, microcomputers, office automation, and the interaction of energy systems and the environment. This instruction would be based on the mathematics, science, and engineering concepts introduced in successively increasing depth in the earlier years. This pattern should contribute measurably to the achievement of technical literacy by the completion of grade 12.

Role of the Computer

Because of its current and future importance, the electronic computer with suitable display modes, particularly the microcomputer version, can have an important curricular role throughout K-12 instructional levels. As a tool, it allows simulation and demonstration of scientific principles, provides a convenient means of performing mathematical calculations, and permits students to study the effect of parameter variations in systems under consideration. As an illustrative technological product, the computer affords many learning opportunities. Finally, because of the pervasive influence of the computer in our daily lives, it constitutes an important stimulus to learning mathematics, science and technology.

A unifying theme for the integration proposed could be associated with the rapid development of the computer and its increasing importance in the life of each individual. There are already strong pressures to deal with computers and their applications in both elementary and secondary schools. The connection between computers and high technology is direct. This fact, plus intense public interest, may well be of enormous advantage in obtaining broad support for the actions that are recommended.

REALITIES OF IMPLEMENTATION

Implication of Recent Attempts at Change

With approximately 17,000 school districts in the United States, one can really only talk in statistical terms about implementing change in the educational system. There is anecdotal information at hand at the extremes of pessimism and optimism and virtually everything in between. Some members of the Advisory

Committee have reported their direct observation of lack of success in effecting improvements in mathematics and science instruction through means such as attempts to obtain pay differentials for science and mathematics teachers, a longer school year, and increased high school science and mathematics requirements at the school district level. Substantial demands on teachers' time both in and out of the classroom, and a timidity of some in dealing with science and mathematics have also been given as reasons to believe that implementing the kind of change proposed is very difficult.

On the other hand, we see examples of substantial success in introducing instruction associated with modern computers in the elementary school which augur well for the future. For example, in the city of Falls Church, Virginia, under the leadership of the principal in an elementary school containing grades K-5, curriculum materials have been developed, on-site graduate courses have been provided for teachers, computing equipment has been made available, and without the introduction of new formal courses, a substantial change has been made in the education the children receive in this subject area. Apparently, the process has been received enthusiastically by students, teachers, parents, and the administration of the school district. Furthermore, it appears that the program did not involve significant budget changes. To a large extent, although admittedly only a very narrow subject is involved, this is a microcosm of what one would want to occur ultimately on a national scale.

We also see some interesting examples of successful cooperation between industry and local school systems, which have improved instruction in science and mathematics. These include a science teacher's workshop sponsored by industry, and a science consultant's program which brings scientists and engineers from industry into elementary schools to give demonstrations and provide "hands-on" experience to students. Several state universities have developed special programs that provide technical updating for science and mathematics teachers and coordination between high school and college instruction. Substantial additional progress in similar cooperative ventures is anticipated.

Curriculum Materials and Teacher Development

Even though one can be inspired by these specific accomplishments, we recognize that integration of science and technology into the precollege curriculum in the manner and to the degree suggested will not be easy. At present, very little material that can be used to address the desired objectives is available to the elementary and secondary school teachers. This educational material must be prepared by individuals having the special knowledge required, working with classroom teachers, and carefully tested before it is mass marketed. This material must also include simple but effective laboratory demonstrations. Effective use of these teaching resources will also require the training of the present teaching staff to deal with the unique nature of the interface between science and technology, as well as the hiring of new teachers who have been exposed to this integrated concept and are dedicated to providing an enriched experience for their students.

Specific information regarding engineering and applications of science is needed to supplement and/or revise textbooks for use in courses on mathematics and social studies. Some of this information has already been developed, but only on a small scale and without the emphasis recommended in this report. Experienced personnel in the engineering profession have indicated a willingness to help provide examples and problems for mathematics, chemistry, physics, and social science texts. Another possibility is to utilize the talents of historians of technology to contribute material for new social science texts. Case studies developed for engineering students at the college level have been in use for some years. These often involve relatively small, short-term projects which include the concepts of synthesis and analytical decision making. Other case studies directed to a less sophisticated student body can and should be written for a high school audience.

A program aimed at teacher development could provide paid summer employment for junior and senior high school mathematics and science teachers. The arrangement would enable teachers to work directly with researchers and designers in engineering colleges and in industrial organizations. This practical experience should give substantial background for enriching the mathematics and science instruction. Cooperative arrangements between business and high schools, which have been developed for distributive education, for example, provide useful models for successful interaction. Another pattern of interest is the activity, sponsored by the NSF, of employing undergraduates in research projects.

Importance of the Individual Teacher

Careful consideration should be given to the development of curriculum materials, the organization of teacher training programs, and the provision of enrichment activities, such as field trips and classroom demonstrations by visiting scientists and engineers. At the outset, we note that in the hierarchy of learning difficulty, synthesis is at the highest level of difficulty. Thus, to achieve the desired level of integration of mathematics, science, and technology, the teaching material must be prepared with considerable care to achieve "teacher friendly" characteristics. The individual teacher will ultimately need to be convinced emotionally that the "technology today" aspects of mathematics, science, and social studies are as necessary in the educational programs for young people as the traditional "facts". The problem, then, becomes one of finding the time to treat the new topics to be introduced. What, for example, will be eliminated? Preparation of curricular materials and design of teacher training programs must be accomplished with this in mind. Furthermore, field trips and demonstrations by outsiders need to be scheduled and structured to achieve continuity in instruction, and provisions must be made to ensure that the individuals participating can relate to the students at the various grade levels.

To achieve success in an integrated approach to instruction in mathematics, science, and technology, it is vital to obtain the involvement of a large percentage of master teachers. These individuals, regardless of their specific teaching specialities, have much to contribute to the development of curriculum, teaching materials, and teacher training programs. The creation of prestigious NSF fellowships for the participation of master teachers in a cooperative effort with engineers, scientists, and mathematicians would provide significant motivation for the contribution of the talents of the teachers.

ROLE OF THE ENGINEERING PROFESSION

The manner in which the engineering profession in the United States is organized can be of considerable advantage in the implementation of the central recommendation of this report. There are national societies associated with the various technical disciplines that constitute the field of engineering. Each of the societies has provisions for communicating with its members on a local as well as national level. The American Society for Engineering Education (ASEE), as the name implies, is composed of individuals concerned specifically with engineering education. There is good communication among the various engineering societies; in fact, there exists an "umbrella" organization, the American Association of Engineering Societies (AAES), whose members are the major engineering societies. The organizational networks available through the various societies provide unusual opportunities to communicate with many engineers in government, industry, and academe and to obtain their volunteer services in facilitating the implementation of the educational changes which are proposed.

Past experience in developing new instructional programs in mathematics and science indicates that a minimum time period of three to five years is typically required to go from concept to a reasonable level of operational performance. Thus, there is an important need to achieve continuity of interest and effort on the part of the engineering profession if it is to make its most effective contribution in this integrative program of resource development. Formal involvement of several engineering organizations of the profession should, therefore, be an asset.

Field trips, "hands-on" demonstrations, and specialized participation by scientists and engineers in industry are important means of enriching educational experiences in grades K-12. Cooperation between school systems and industry would be beneficial in teacher updating and in the sharing, or loaning, of specialized laboratory equipment. At a local level, engineering schools constitute an important resource to deal with these opportunities. Task forces operating on a cooperative basis among several engineering societies at a national level would assist in developing resource material for teacher training and for curriculum development, including laboratory exercises.

CONCLUSIONS

In recommending changes in mathematics, science and technology education in levels K-12, the Commission should give serious consideration to the introduction of engineering concepts and their integration in mathematics and science material, including practical applications, within courses in many subjects throughout the curriculum. This action is necessary to ensure that all graduates completing instruction through grade 12 achieve general technical literacy, as well as to improve the precollege preparation of students intending to pursue professional careers in mathematics, science, or engineering. Separate courses should not be used to present the material recommended; instead, the concepts and applications should be introduced by modification of existing courses.

Curriculum materials, including laboratory exercises, will have to be prepared to make the recommended transition feasible, and various forms of teacher training also will be necessary. Case studies, including design and synthesis, analogous to those developed for engineering undergraduates should be developed for the high school level. Summer programs which enable mathematics and science teachers to interact as participants with research or design groups in universities and industry should be instituted. The engineering profession, acting through its professional societies and the engineering colleges and universities, could assist materially in the transition process, including facilitating arrangements for cooperating with industry.

ATTACHMENT 1

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4

FUNDAMENTALS IN PRECOLLEGE TECHNOLOGY EDUCATION

Report from the Junior Engineering Techical (JETS) Society
Prepared by Paul J. Sullivan, *JETS*

Meeting Chaired by John G. Truxal, *State University of New York, Stony Brook*

EXECUTIVE SUMMARY

Introduction

JETS INC.—the Junior Engineering Technical Society—held a workshop on Aprl 18 and 19, 1983 entitled "Fundamentals in Precollege Technology Education." The purpose of the meeting was to examine the current status of precollege technology education and recommend to the National Science Board Commission on Precollege Education in Mathematics, Science, and Technology ways to improve the technological literacy of graduating high school students.

Questions Raised

The group addressed four key questions:

- What concepts in technology and engineering should be taught to young people?
- When should this material be introduced?
- Where in the curriculum could a place be found to best accommodate technology?
- How do we reach the students who seem to "opt out" of science and mathematics courses early in their schooling?

It was agreed that technology is not dealt with effectively now. There are few teachers knowledgeable in technology. Consequently, many teachers are often timid about technical subjects and do not incorporate technology into their lessons. Moreover, there is no provision for including technology in existing courses, and whatever students receive is too little, too late.

Since technology is a set of tools for students to use, it is important that all students have a positive experience with technology throughout their school years, from grade K through 12. While mathematics and science classrooms are the traditional homes of technology, an understanding of technology can be achieved in other subject disciplines as well. There is a need for technical concepts to permeate the entire precollege curriculum, and to be taught with real-life examples.

General Recommendations

A. *Grade K through Elementary Years*

As early as practical, students should become aware of the impact of technology on their lives. Stress should be placed on the importance of modern technology through relevant examples and hands-on technological activities. During these years considerable attention needs to be given to developing mathematical and reading skills of young people.

B. *Middle School Years*

It is in the middle school/junior high school years that much can be done to ensure technological literacy of young persons. We should use technology as a way of introducing the individual disciplines of mathematics and science, and stimulating greater student interest in these disciplines.

Career information for students in most fields—including science, mathematics, and engineering—is inadequate now. Career information should be introduced as early as elementary school, and should be expanded upon in middle school. This would enable students to choose their courses in high school more intelligently, and help them decide their appropriate plans.

The middle school should emphasize oral and written communicative skills. The mathematics curriculum should concentrate on practical applications of mathematics showing students that mathematics is a useful tool relevant to their future.

It is recommended that a course in technology and technological thought be developed for use either at the eighth or ninth grade level. This is an appropriate time to cover subjects in technology indepth, rather than waiting until the last year of high school.

C. *Secondary School Years*

In the high school years we need to further strengthen the oral and written communicative skills of all students as they begin to depend more on these skills more outside the classroom. Also during these four years we should have students examine technological systems that make up their world. A whole range of skills and concepts should be incorporated into the mathematics and science curriculum so that students could better appreciate these systems. For those students more interested, it is recommended that schools make efforts to involve students in club activities in science and technology.

The development of problem solving skills should be a fundamental goal in precollege education. This provides further rationale for an early introduction to technology. The early introduction to technology, giving examples of real problems, would develop important reasoning skills.

Computer Use in the Schools

Computers are extraordinarily important tools for young people. Rather than strictly as a form of educational technology, students should be shown that computers are tools they will use in their future and, consequently, should know and become familiar with them. Computer use should be introduced in the elementary grades, and all students should be familiar with microcomputers by middle school. The computer can then be used more naturally by the high school student.

Conclusion

One result of this workshop was the strong recommendation that a foundation in technology be regarded as fundamental as reading and writing for all—not just for the high-achiever for whom excellent curricula and materials have already been developed. It was felt that every student deserves to be aware of the impact of technological advance and able to understand the underlying technology itself. An understanding of technology has rarely been thought of as important for every high school graduate in order to ensure their literacy in this culture. Now society must ensure that an understanding of technology be a part of each student's basic education.

Many specific recommendations were developed, which are given in detail in the accompanying final report of the workshop.

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1. INTRODUCTION

The National Science Board created a Commission on Precollege Education in Mathematics, Science and Technology in April of 1982 with the purpose of defining a national agenda for improving elementary and secondary education in mathematics, science, and technology. This was to include an action plan defining the appropriate roles for federal, state, and local goverments, professional and scientific societies, and the private sector in dealing with currently perceived problems in precollege education.

One of the more difficult tasks for the Commission has been in the area of technology education for precollege students. Science and mathematics are currently taught in the precollege years and can be examined to determine how to be most effective. Technology is not a subject typically covered in school, and is available to students only through occasional references in other subject areas.

The Commission sponsored three meetings to examine fundamentals in the precollege curriculum. The first examined mathematics, the second science, and the third meeting—ways of introducing technology to precollege students.

It was recognized that the rapid advances of science and engineering have left many of the public uneasy and confused about how new developments will affect their lives. These advances have also given rise to technological illiteracy and professional shortages—conditions which can only be arrested by changes in the earliest school grades.

Twenty-five or thirty years ago there was great glamor attached to mathematics and science as a means to a national goal and students were required to complete a core in these disciplines. Ten or fifteen years ago, however, students were allowed a broad choice in their educational pursuits and often chose, in their pursuit of relevancy, subjects other than mathematics and the "hard" sciences.

Today we should consider these aims—material goals and relevancy as perceived by the student. This can be achieved by developing meaningful curricular topics related to the student's background. For example, "hi-fi" can be used as subject matter in the investigation of problems involving physics, mathematics, psychology, economics, government, and perhaps more.

Engineering is a people-oriented, learned profession, which must be recognized as such by the precollege professional educators. Engineers must be involved in all phases of curriculum development to better assure that matching subject matter is presented to precollege students with their other course work.

2. QUESTIONS RAISED

The workshop attempted to focus on specific questions in order to establish what ought to be expected of high school graduates. Each of the groups presented what they need in a graduating high school student.

The workshop addressed only four questions:

- What concepts in technology and engineering should be taught to young people?
- When should this material be introduced?
- Where in the curriculum could a place be found to best accommodate technology?
- How do we reach the students who seem to "opt out" of science and mathematics courses early in their schooling?

It was widely agreed that technology is not dealt with effectively now. There are few teachers knowledgeable in this field. Consequently, many teachers are often timid about technical subjects and do not readily incorporate them into their lessons. Moreover, there is no real provision made for including technology in existing courses, and whatever students receive is too little, too late.

3. BACKGROUND

The National Commission on Excellence in Education recently stated that:

> ". . . the average citizen today is better educated and more knowledgeable than the average citizen of a generation ago . . . nevertheless, the average graduate . . . is not as well-educated as the average graduate of 25 or 35 years ago."

Relating this statement to precollege experiences of our young people means that the educational system has not kept pace with technological advances.

The use of the term "precollege" in all discussions of K-12 education tends to imply concern for college-bound students exclusively, yet we are concerned about the technology education of *all* students. Public understanding of technol-

80

ogy must be greatly improved, and the most fundamental way of accomplishing this is to work at it through the schools.

Technological literacy needs to be a part of general literacy and "numeracy." In a sense we are speaking of "basics" in education, and we are identifying the knowledge and understanding of technology as basic. Technological literacy is quite different from scientific literacy and mathematical literacy. An understanding of scientific and mathematical concepts doesn't automatically result in an understanding of technology.

Technology is a product of mathematics, science, and engineering. It is difficult to introduce the concept of project work and design of physical things into an academic environment. What is principally lacking is faculty experience in technology; thus, we must better prepare our teachers. The education of teachers in technology must be, in part, experiential, so that they can educate students in an experiential way.

We need to have teachers who deliver knowledge of science and technology in a manner that brings understanding, appreciation, enthusiasm and support. Instead, sometimes the way the science is taught brings misunderstanding, frustration, and mistrust of science and technology.

Real problems—the products of technology—provide numerous exciting applications of mathematics and science. The examination of these problems can motivate students to take and continue in mathematics and science. When technology is used to introduce scientific thinking, it will appeal to the student as more interesting and relevant, and hence be a motivator. The mathematics and science education now offered to our young people could be greatly enriched if we were to incorporate a technological content.

In precollege programs, engineering has been most closely associated with vocational education, and that view can no longer be perpetuated. The teaching of technology should be linked with basic mathematics and science education. It will create a more enriching intellectual experience for the student who is trying to cope with technology. The powerful potential of engineering ideas should be a part of everyone's education.

4. DEFINITION OF TERMS

To place the work of the group in context, definitions were sought for both technological literacy and technology. The wording varied widely, but most definitions offered led in the same direction. The statements given here are serviceable, and reflect a synthesis of the thoughts of many workshop participants.

> *Technology* consists of the tools, devices, and techniques that have been created to implement ideas borne of science and engineering. Technology exists to manage and modify the physical and biological world in a constructive way and relies on a foundation of mathematics. Technological systems result from engineering design and development.

> *Technological literacy* is the possession of a reasonable understanding of the behavior of technological systems and requires knowledge of scientific and mathematical concepts. Along with this must go an understanding of certain underlying concepts that are unique to engineering.
>
> People must understand the limitations as well as the capabilities of emerging technologies. The technologically literate person should have a sense of what technology can and cannot do. He or she should not believe that technology can solve all ills, nor that technology is responsible for most problems.
>
> Contributing to technological literacy is an understanding of: (1) the historical role of technology in human development, (2) the relationship between technological decisions and human values, (3) the benefits and risks of choosing among technologies, (4) the changes occurring in current technology, and (5) an understanding of technology assessment as a method for influencing the choice of future technologies.

As is true of literacy in any subject, technological literacy exists on a continuum. Different persons exhibit different levels of competency and understanding. Our curricular developments and training in technology need to foster the comprehensive understanding indicated above.

5. TECHNOLOGY AT THE PRECOLLEGE LEVEL

The workshop participants began with a predisposition that technology is, in fact, a necessary part of the precollege experience for young people. Yet there was discussion on the reasoning behind that starting point. There were several fundamental reasons stated for teaching technology in an effort to develop technological literacy. These form the rationale for increased efforts toward teacher education, curriculum development, and other related activities.

Rationale for Learning Technology at the Precollege Level:

1. People must know about technology in order to improve the quality of many personal and professional technology-based decisions.
2. Technological literacy prepares individuals for intelligent participation as informed citizens in the transition from an industrialized society to a post-industrialized service and information age.
3. Technological literacy will encourage greater participation by individuals in shaping public policy, which often involves the use of sophisticated technology. It will tend to encourage civic responsibility and overcome voter torpidity, which can arise out of a lack of understanding of new technologies.

The intent is to strengthen young people early with the awareness and flexibility that comes with technological literacy.

6. RECOMMENDATIONS

Workshop participants had detailed discussions over a one-and-a-half day period. These were accompanied by several formal presentations. The purpose of this report is to distill these discussions into a set of recommendations to be considered by the NSB Commission, as well as by educators who are strongly involved in science and mathematics education. These recommendations are presented in the following seven sub-sections, and are broken out in isolated categories. The reader should realize the degree to which many of these recommendations overlap. Technology must be approached by the entire school, by agencies that work with the schools, and by the family. This highlights the presumption that technology education should be regarded as fundamental for all young people.

A. *Curriculum Revisions*

Technology education can be introduced into the schools in a variety of ways. The following represent aspects of technology education that affect the curriculum offered.

1. Technology topics need to be integrated into the present curriculum. This includes science and mathematics classes, industrial arts, social studies and the language arts, and art and music.
2. When designing how to best infuse technology into the curriculum, think in terms of the average student in the early grades. Then offer a specialized curriculum in the last two years of high school for the college-bound student.
3. Integrate new units into existing courses of study in secondary school. The key is to develop technology-based materials that can be matched properly to what the students are already being taught.
4. It is recommended that a course be developed for use at the eighth or ninth grade level. This would be an introduction to technology and technological reasoning, and would be either offered in lieu of or in conjunction with the normal general science course. This sequence would move the 3-2-2 program proposed at the science workshop to grades 10 to 12 making possible the objective of requiring science through grade 12.
5. The following material is recommended as an outline for what ought to be covered in any precollege instruction on technology. It is only a partial outline, representing some principal subjects that students must deal with regularly.

a. *Technological Systems*

Students should have an opportunity to examine:

Communications
Energy Production and Conservation
Transportation
Shelter

Food Production
Health Care Delivery
Safety
Residential Use of Space
Resource Management
Biotechnology
Computers and Their Applications
Nuclear issues

b. *Concepts*

Students should have some education in:

Problem formulation and solving
Debugging a problem
Discovering alternative solutions to problems
Making connections between theory and practice
Pattern recognition
Engineering approaches to problems—Evaluating trade-offs
Probability/Approximation/Examination
Building and testing of equipment
Examining trade-offs and risk analysis
Economic decisionmaking
Feedback and stability
Recognizing orders of magnitude

Topics in the *Man Made World* text, which was supported by the National Science Foundation, should be examined and relevant topics be prepared for the general student. The *Man Made World* was created with college-bound science students in mind. The material is worthwhile, and needs to be communicated to younger students who may not be college-bound. These technical/people/environmental mini-courses represent a pilot effort to reach the noncollege-bound.

c. *Learning Objectives*

1. Examine the personal and societal impacts of technology; the effects technology has on an individual as citizen and consumer.
2. Gain a knowledge of interactions of society and the environment using technological problems and their solutions as practical examples.
3. Develop confidence in the ability to analyze a problem.
4. Learn practical uses of mathematics through relevant problem-solving.
5. Secure a sense of what is possible and not possible through science and engineering; a grounding in reality.
6. Obtain the ability to communicate a solution of a problem to other persons, both orally and in writing.

7. Experience an awareness of the joy of learning about technology and the underlying curiosity that advances technology.

6. Technology should be used as a way of unifying the teaching of science at the secondary level. Students in secondary schools usually learn concepts and skills in a fragmented and discipline-based environment, evolving from tradition more than from student success. Students seldom become involved in the search for solutions of real problems.

7. There should be a de-emphasis on lectures in favor of activities in problem solving, modeling, estimating, probability, and statistics. The ISIS and NC^3D applied science and mathematics modules are examples of an attempt to do this.

8. Courses that result from the integration of technology into the existing curriculum need to be quite strong. There needs to be greater emphasis on student performance, and a broader core of requirements in order to graduate from high school. For example, there should be no substitute for algebra in high school; it should be a requirement.

9. There needs to be an effective dissemination of existing curriculum projects. Many valuable tools already exist in technology education, but have been poorly distributed to the teaching community. This ought to be taken into account before new curriculum materials are developed.

10. The curriculum projects not yet completed within the National Science Foundation should be evaluated, and certain of them completed. This would add to the pool of available materials at minimal cost.

11. Career education needs to be introduced early in the student's schooling and should also be integrated into existing science and mathematics curricula. (See Section E of this report.) An abundance of career education material exists, thus, it would be easy to begin introduction immediately.

There is a significant need to be concerned with implementation strategies prior to the development of new curriculum materials. There could be faculty opposition to changing or possibly "diluting" traditional mathematics and science courses with content in technology or material on career education. Yet the application of technology to other subject areas (English, social studies, *et al*) may encourage the science and mathematics faculty to embrace it as well in their classrooms.

B. *Support Systems*

Beyond the curriculum itself, there are a number of structures that can support teacher attempts to bring technology into the classroom. The following recommendations are meant to ensure the successful introduction of technology.

1. Technology as a content area should be integrated into preservice and inservice education of all teachers. A minimum understanding of technological concepts should also be a prerequisite for certification.

2. The value of summer study institutes for teachers has been well documented. These have not been offered regularly in technology. Summer institutes in engineering concepts and applied science should be sponsored for precollege teachers by the National Science Foundation.
3. Summer programs for precollege students should also focus on technology. There is need for additional summer institutes in which bright high school and middle school students are introduced to technology. Summer sessions either conducted or coordinated by JETS could serve as models.
4. There are many youth-serving programs in the area of science and technology that receive little public recognition. Many are regional, yet some are national in scope. These successful student programs need replication and transportation to additional schools and students.
5. Club activities have a long-standing success rate for interesting students in academic areas and for encouraging high academic performance. Club participation in technology should be encouraged, where the possibilities for hands-on activities are numerous. Engineering design contests lend themselves well to student clubs. There are several existing models for club participation; i.e., JETS, National Honors, Mu Alpha Theta, etc.
6. Science and mathematics departments should look to the Industrial Arts teacher as a resource in the incorporation of technology into many parts of the student's work. Work in Industrial Arts can provide some hands-on approaches to technology, especially when related to mathematics and science.
7. Additional research is required in the cognitive sciences to measure the performance and achievement of students in science and mathematics.
8. Enormous resources are available to teachers and students in the local chapters of engineering professional societies. The society members are usually willing and able to work with students and to advise them, if a specific approach is made to the chapter. Greater communication is recommended, beginning with professional societies actively approaching the local school system and responding promptly to their requests.
9. Secondary and middle schools with the most successful students in mathematics and science are usually in close communication and cooperation with area universities. Connection with the colleges of engineering is more limited. It is recommended that schools rely more on the area college of engineering as a resource for professionals and ideas.
10. There is a need for an oversight group such as NSF's Science Education office, to concern itself with issues in science, mathematics, and technology education on an ongoing basis and to monitor the imple-

mentation of actions recommended by the NSB Commission. An oversight group could make available the wealth of material that exists on education in technology (regional programs, curriculum modules, etc.).

An ongoing partnership is needed between engineers, college level educators, and industrialists with those responsible for precollege curriculum and teachers in order to make progress toward true implementation of technology in the classroom.

11. Since the inadequate preparation of students in mathematics, science, and technology has been identified as a "crisis" of national proportion, we need to embark on an ambitious campaign with specific goals for our young people. There needs to be an organizational structure that centralizes much of the planning and development of training and materials. Structure and focus are required if there is to be any meaningful progress. To this end, we support the proposals advanced in the science workshop.
12. Work with political structures and local school boards is needed to have them realize the importance of technology education and to solicit their help in making change possible.

C. *Treatment of Teachers*

There are a host of issues that affect teacher quality and shortages. The basic point is that the teacher is the key to successful and lasting education for students. The teacher carries out plans and changes that are suggested for the educational enterprise. Hence, much of our effort must be directed toward improving the treatment of teachers and improving the environment within which teachers perform their professional task.

The introduction of technology as a legitimate part of the curriculum is suggested now at a very difficult time for teachers and the schools. We must, therefore, work at solutions to teacher stress as we strengthen mathematics and science instruction.

We recommend focusing on four principal themes:

1. Curriculum development is an empty enterprise without sufficiently well-paid faculty in schools. Many of the above recommendations will be ineffective, if quality teachers are not better paid and given incentives to stay in teaching. A pay scale including merit factors should be developed and used.
2. Teachers already in the schools and in-coming teachers must be offered a substantive education in technical disciplines. They cannot be expected to pick it up on their own time, nor should it be difficult for them to obtain.
3. Teacher unions need to be brought into the process of innovation. They have a significant control over the teaching enterprise and, so, must be considered a partner.

4. To ensure the place of technology in the classroom, school boards need to be shown the value of science and technology in the school curriculum. They are the source of funding and approval for any teacher innovation that is to be encouraged from the outside.

Extensive reporting has been done on current teacher shortages. The reader is directed to the work of the National Science Teachers Association on this subject. Resolution of teacher shortages in science and mathematics is critical to the successful introduction of technology into the precollege curriculum.

D. *Approaches to Technology in the Schools*

Since technology is a set of tools for students to use, it is important that all students have a positive experience throughout their school years, from grades K through 12. We recommend that technology education be given attention throughout the precollege years with both the amount of coverage and the complexity of the examples used increasing as the student approaches high school graduation.

Because technology affects all facets of society, ideas related to technology should be introduced in all appropriate subject areas. There is a need for technological concepts to pervade the entire precollege curriculum.

1. *Grade K through Elementary Years*

As early as practical students should become aware of the impacts of technology on their lives. Through relevant examples and hands-on technological activities, stress should be placed on the importance of modern technology. It is an ideal time to foster respect for humanity and to develop a sense of stewardship of the planet.

During these years there needs to be considerable attention given to developing the mathematical skills of students. They should gain a strong grounding in arithmetic as a foundation for future use of mathematics as a tool. Reading can be a method of incorporating science and technology into a young person's school day. There should be opportunities in reading lessons to learn about individuals in science and technology as well as simple content material. Science can best be introduced as "applied science," which is technology.

2. *Middle School Years*

It is in the middle school/junior high school years that much should be done to improve the eventual technological literacy of a young person. We can use technology as a way of introducing the individual disciplines of mathematics and science. Technology can make education in these years more interesting, relevant, and stimulating than current coursework. It can be used to stimulate students to a greater interest in mathematics and science.

Technology can turn students on in the early grades and motivate them to assert themselves in these middle years. Often when pure science is introduced on its own students are turned off, and it is very difficult to interest them again in scientific subjects. In this age the study of technology can take advantage of an adolescent's natural curiosity of the world around him/her.

During middle school years we should emphasize oral and written communicative skills. The mathematics curriculum should concentrate on the practical applications of mathematics showing students that mathematics is a useful tool.

This is an appropriate time to cover subjects in technology in more detail, rather than waiting until the last year of high school. Hence, we recommend that eighth or ninth grade be used to offer an introduction to a technology course. This should not follow the same pattern as the *Man Made World* curriculum, which was for older students. Rather it should be designed to be useful to all students about to begin their high school sequence.

3. *Secondary School Years*

In the high school years we need to further strengthen the oral and written communicative skills of all students as they begin to depend more on these skills outside the classroom. Also during these four years we we should have students examine technological systems, which make up their world (health care, transportation, energy, communications, etc.). A whole range of skills and concepts should be incorporated into the mathematics and science curriculum so that students could better appreciate numerous technological systems. (Sections 5a and b above present a partial listing of systems and concepts for students.)

This is the time during which students, who are most interested in technology, should be encouraged to participate in club activities in sciences and technology. JETS chapters can serve this end.

The development of problem solving skills should be a fundamental goal in precollege education. This provides further rationale for early introduction to technology. This early introduction to technology, giving examples of real problems, can develop these important skills. This is problem solving as used to advance technology.

By this time students should have a good command of mathematics and should be using microcomputers as tools for other coursework. It is suggested that students become familiar with word-processor software usage, because this skill will be very helpful in their later work.

Competency in mathematics and science is important for both college-bound and noncollege-bound students. Hence, schools should adopt higher minimum standards in science and mathematics than are presently the norm for graduation from high school. This will give a greater advantage in the market place to students who are noncollege-bound.

All students require equal access to education in technology, and one of our goals is to provide all graduates with a knowledge of basic skills. Special attention must be given to students completing their formal education with high school. Drawing from the curricular recommendations of this report, schools and teachers need to be sensitive to providing strong exit skills in technology.

E. *Career Education*

Career information for students in most fields—including science, mathematics, and engineering—is now inadequate. Career information should be introduced earlier—even as early as elementary school when students are forming attitudes toward education and the world. It should then be repeated and expanded in the middle school. This will help students make knowledgeable decisions about their next level of education and their career paths. They will then be able to choose their high school courses more intelligently. For example, if students are made aware of the need for strong precollege preparation in mathematics as an entry requirement for many technical job paths, they will not close off their options unknowingly.

Career education makes more sense if it is related to things that students are currently learning in class. Information can be included along with subject matter in the entire curriculum offered.

Students must neither be given unrealistic expectations nor tracked into a career path too early so that other options either become difficult for them or are denied. By providing career information early, however, we can ensure that students realize the education and training that is required for certain career paths. The emphasis should be on the flexibility of career choice that comes with a strong background in mathematics, science, and technology.

F. *Computer Use in Learning Environments*

Although the computer is far from reaching its true potential as a learning tool, it should become an important part of today's educational scene. One beauty of the computer is that it can be used to introduce young people to technology through well-prepared software, and through its use students would be interacting with technology itself.

There is a call for computer literacy, yet this should be regarded as but one aspect of a fuller technological literacy. The computer is but one of many expanding modern technologies. Microcomputer-based learning should be used to help students become more literate in many areas of technology.

There have been references made to computer education in both the mathematics and science workshop reports to the NSB Commission. In the context of technology education, participants at this workshop supported the recommendations of the prior two workshops and advanced several of their own recommendations regarding the use of computers as a teaching tool.

1. For the most part the hardware is in place, but quality software is not. There is a significant need for educational software (courseware) which will encourage effective use of computers in the classroom. The National Science Foundation should consider funding promising courseware developments.
2. Software and curriculum should be developed in unison. Much of the present difficulty lies in software that has been poorly adapted to existing curricula.

3. Quality computer-based courseware should be available in all learning environments—the home, libraries, community centers, as well as in the schools. The growth of personal computer sales must be matched by the development of educational software, which can be used in the environments where young people live.
4. A prime reason for the slow introduction of computers into schools is the unfamiliarity of teachers with these tools. Immediate training is required for teachers, and this should be subsidized to make it readily accessible to teachers of all grade levels and economic areas.
5. For the use of computers to be effective with students in the schools there needs to be an appropriate classroom environment for their work. It is recommended that lecture/laboratory arrangements with enough available hardware for every student to have sufficient access to an input/output device be provided. It is very helpful for the instructor to have an interactive capability with each student terminal. This allows for software development or testing with the confidence that student acceptance or rejection of the curriculum is not based on frustration with work space or hardware.
6. Students should learn to use computers as an aid to further learning. The computer should be used as an instructional tool for: (a) management of instruction, (b) drill and practice, (c) tutorial learning, (d) problem solving, (e) simulation, (f) creation of microworlds (as in the LOGO language).
7. The use of the computer by the student should, as with any educational technology, become a routine task.
8. Schools need guidance to avoid the indiscriminate purchase of hardware and software. This help could come from either federal agencies charged with education or from engineering societies.

The existence of the computer, and its ready availability in the classroom, may well be the greatest stimulus for the development of new curricula for the schools. It is hoped that this will provide an opportunity, in many cases, to introduce broader issues of technology to students.

The computer may serve as a strong unifier within the school. Use of the computer will spawn creativity for the above average student, and will act as a tool to improve the performance of the average student. The two groups come together in using a single technology.

7. CONCLUSION

Our goal is to better introduce young people to technology and its impact on society prior to their graduation from high school. This should make them better citizens and consumers and stimulate them to the learning of science and mathematics. Yet there must be recognition by society that technological literacy is fundamental in order for the schools to embrace it and then expect it of students. This recognition will take time to appear, and what we introduce now as new initiatives may take several decades to implement fully.

The school system K-12 reflects the interests and desires of society. As technology changes, our understanding of it, as a society, will depend on our ability to teach clear thinking skills and problem solving procedures to our young people.

The study of technological systems should be used as a basis for providing integrated and holistic learning. This is our reason for suggesting that all academic departments be involved. We cannot afford to repeat the mistakes of the past. If we are to embark on this revitalization of the secondary school and middle school experience, it must be a task that intimately involves the students, faculty, and staff of these institutions. Too much of our curriculum development and materials preparation has been done exclusively by individuals in higher education who have little knowledge of how high schools and middle schools work. There must be a stronger working relationship between these two groups to eradicate this unfortunate disassociation of the curriculum from the reality of the schools. High school people must be involved not just as end users, but also in the initial stages of planning and organizing the curriculum in technology.

The engineering community needs to work closely with leaders in science, mathematics, English, industrial arts, and social studies curriculum development to convey the importance of technological content for their work. The engineering profession must also be called upon to assist in "marketing" technology study to schools and students. It is not just going to happen if the schools are told to incorporate technology education. Technology is foreign to the schools and, as a result, they need outside help, which can and should come from the profession.

Engineering colleges and engineering professional societies should commit their institutions to contributing to the development of technological literacy. The talents of individuals, who have great expertise in science and technology, have to be called upon. These are individuals who are often unfamiliar with the problems of the schools. There needs to be considerably more communication between advanced researchers and the precollege community.

The need to integrate technology into the precollege curriculum gives us an additional reason to foster partnerships among business, industry, and education. Collaborative efforts are the only reasonable approach to complex problems of this sort. Schools cannot achieve solutions to all of America's social problems, and thus, we need to again focus their task on the teaching/learning process through new partnerships and revitalization.

True learning includes first, a sense of accomplishment and satisfaction, second, an excitement which generates further exploration, and third, a desire to relate this new ability to other areas. It is our position that the study of technology can stimulate this cycle and foster true learning in science and mathematics as well. Beyond all practical reasons, we encourage the study of technology by young people strictly for the simple joy of it and for the great satisfaction that comes with an understanding of how the world works.

Fundamentals in Precollege Technology Education
A Workshop on Technological Literacy
18-19 April 1983
United Engineering Center—New York City
FINAL AGENDA

Monday, 18 April

8:30–9:00	Coffee and registration.
9:00–9:15	Welcoming Remarks: Dr. Roy Cowin Executive Dirctor, JETS Inc. Paul Sullivan, Workshop Dirctor Associate Director, JETS Inc.
9:15–9:30	Report on the work of the NSB Commission on Precollege Education.
9:30–9:45	Workshop theme and introduction; statement of purpose: Dr. John Truxal, Workshop Chairman Distinguished Teaching Professor, College of Engineering State University of New York, Stony Brook
9:45–10:00	Report on previous curriculum efforts in technology education: Dr. E. Joseph Piel, Department of Technology & Society State University of New York, Stony Brook
10:00–11:30	Plenary Session. What should we expect of our high school graduates? Perspectives from constituent groups; expression of their needs: University educators (engineering & liberal arts). Precollege educators (teachers and administrators). Industry as employers. Military as employers. Teacher preparation; schools of education.
12:00–1:00	Luncheon (Room 110)
1:15–3:00	Working Groups (report to individual conference rooms as assigned): Discussion of the major workshop questions: 1. What should be taught? Concepts in technology and engineering that would help to insure technological literacy among all students.

2. When should it be taught?
A look at the middle/junior high school years and at the high school years.

3. Where should it be taught?
Where in the curriculum is there a place for technology education?

4. How do we reach the "non-science student"?
What should the message be?

3:00–3:15 Coffee break.

3:15–4:45 Reports of the Working Groups, with discussion.

Formulation of *recommendations* based on the Working Groups.

5:00 Adjournment.

Tuesday, 19 April

Coffee will be available at the morning session.

8:30–9:00 Review of suggested recommendations on technology education (priorities).

9:00–10:0 Plenary Session.

Computer use in the schools.
How best to introduce young people to computer use.

a) report on the computer recommendations of the previous NSB Commission workshops.

b) recent experiences with computer use in the classroom: individual workshop attendees.

10:00–10:30 Working Groups. (report to individual conference rooms)

Formulation of recommendations on computer use.

10:30–11:00 Working Groups (continue with same group):

Implementation Questions.

1. How best to influence the curriculum to adapt for technology education.

2. How best to influence the schools to seriously adopt technology education.

11:00–12:00 Plenary Session.

Reports of the Working Groups.

Reporting the results of the workshop:

a) Formalize the workshop recommendations to the Commission.

b) Input from the group on what form our report should take.

12:00–12:15 Workshop summary and adjournment.

1:00 Luncheon at the United Nations Delegates' Dining Room.

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STRATEGY FOR IEEE RESPONSE TO CRISIS IN PRE-COLLEGE SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION

The IEEE views the well-documented crisis in pre-college education in science and mathematics as a vital agendum for the full participation of its membership. Because of the national dimension of the crisis, the Institute believes that effective and long-term action can be taken only in coalition with other technical and scientific societies and in consonance with the recommendations of govermental bodies now studying the total dilemma. In this sense, the Institute pledges to work with the AAES, ASEE and the Coalition for Education in the Sciences, recently formed by the AAAS to enhance the role of professional societies in improving pre-college education, and to follow the forthcoming Action Plan being developed by the National Science Board's Commission on Pre-college Education in Mathematics, Science and Technology. In the interim, the IEEE EAB will prepare an organizational plan for involvement of the Institute's membership at the section level, such involvement to include, for example:

- urging local universities and colleges to modify admission requirements in order to motivate the pre-college system to respond with greater emphasis on education in the sciences, mathematics, and communication skills from K through 12.
- Interacting with the boards of local school districts to implement modification in pre-college curricula consistent with the recommendations of the NSB Commission's Report.
- Developing IEE Section Awards for excellence in pre-college teaching of science and mathematics, the purpose being to add professional dignity to pre-college teachers and to bring these members of the national team into the professional scientific-engineering community.
- Recognizing locally and nationally those non-technical leaders of the community who have exhibited an astute public understanding of science and technology.

Joseph Bordogna

Description of JETS

JETS is a national, nonprofit organization devoted to the education of secondary school students in the areas of engineering, technology, and science. Also known as the Junior Engineering Technical Society, JETS has been active for twenty-five years as the engineering profession's precollege service organization.

Several national programs are administered by the JETS office in New York, and many others are designed for use at the local level. JETS has an extensive network of students and teachers involved throughout the country. JETS activities depend on the work of school teachers, university faculty, and local engineering societies. Each year about 30,000 students work with JETS in one way or another.

Various publications and test materials are distributed through JETS, and they are a good source of career guidance information.

The JETS program is of particular interest to students who enjoy their coursework in math and science or who are contemplating career paths in engineering, math or the sciences. These programs are designed for the high school student, yet recent efforts by JETS are extending our range to the middle school years. For these younger students, if there is a distinct interest in science and math then the activities of the JETS organization can help to fulfill their curiosity.

JETS is supported by the engineering profession through the professional engineering societies, and by contributions of colleges of engineering and industrial corporations.

5 REPORT ON EDUCATIONAL TECHNOLOGY

Report from a Conference on the Uses of Technology in Education

Prepared by Ludwig Braun, ***New York Institute of Technology***

ACKNOWLEDGMENTS

It is impossible for me to identify and to acknowledge all of the people who helped me to prepare this report. Clearly, all of the participants in the conference who are listed in Appendix A made important contributions.

Certain individuals made contributions far beyond what any reasonable person might expect. Among these are: Carl Berger, Karl Zinn, Norman Kurland, and James St. Lawrence, all of whom continued making comments and suggestions weeks after the conference ended; Ward Deutschman, who arranged the teleconference and kept us all going on the system; and Barbara Zengage and Lisa Sancho, who helped me a great deal in organizing the conference and in putting the report together.

I wish also to thank Dr. Matthew Schure, the President of New York Institute of Technology, who made the NYIT teleconferencing system available to our conferees at no charge. The availability of this system helped very much to keep us in contact during the formative parts of the report preparation.

Finally, I wish to thank Dr. Cecily Selby and The Commission on Precollege Education in Mathematics, Science and Technology for the opportunity to prepare this report.

Ludwig Braun

EXECUTIVE SUMMARY

The attached document reports on a conference held at the New York Institute of Technology on April 24 and 25, 1983, the purpose of which was to clarify the issues relating to applications of technology to education. These issues and the recommendations of the conferees are summarized in the paragraphs below.

Educational Technology—Definition and Domain

The conferees identified six major technologies which have great potential for education in mathematics, science, and technology. These are: computers; educational television; videotex, data bases, and computer-based telecommunications; video discs; intelligent video discs; and robotics. In addition, the conferees suggested exploration of combinations of these technologies, and vigilant attention to new technologies as they emerge, to identify educational applications.

Computers are the most widely-considered technology in the current educational scene. They are used in three separate modes: learning *about* computers, the most-widely used application in education; learning *through* computers (i.e., drill-and-practice, and tutorial), the most-widely researched area; and learning *with* computers, the area with the most exciting potential for computer impact on learning.

Television has a great deal of potential for contributing to learning as demonstrated in the "Nova" series, "Sesame Street," and "3-2-1 Contact," as well as the many college courses offered on TV by colleges.

The remaining technologies considered (as well as others which just are emerging, but which were not considered in detail) have great potential for contribution to learning; however, they all are in exploratory phases of their development and have not yet had great impact on education.

Evidence of Effectiveness

Before we as a Nation bring technology into learning environments on a large scale, we must determine that there is some real value in so doing. The conferees considered that issue at some length, and found very strong evidence that computers, used in the "learning-through" mode, make significant contributions to the learning experiences of children in a variety of disciplines, and that, even though there is much less evidence in these areas of application, computers used in the "learning-about" and "learning-with" modes have a great deal to offer educators and students as well.

The published evidence on educational impact of television also is very strongly favorable, especially when it is accompanied by well-developed support documentation for teachers and students.

Unfortunately, the other technologies considered are so new, at least in education, that there is no published evidence of effectiveness. There only is anecdotal evidence in these areas.

Quality Courseware

The conferees identified several problems related to courseware. These are:

1. The overall quality of existing courseware is very low. There are outstanding materials, but their proportions are small.

2. There is a serious problem of identifying, training, and rewarding people with talent in this area.

3. The investment cost to develop an adequate base of quality computer courseware in mathematics, science, and technology for the Nation's K–12 schools is about $60 million, an amount beyond the levels publishers can justify.

4. There is a serious problem of obtaining reviews of courseware (computer programs, films, and video tapes and discs).

Microcomputers in Informal Learning Environments

Informal learning environments have several advantages over shools, including access by everyone in the community, and creation of a nonjudgmental climate without the time constraints of more formal environments.

Informal learning environments include participatory museums like the Capital Children's Museum in Washington, community-based centers like Playing To Win in New York and ComputerTown USA in Menlo Park, California, and people's homes. The home may be the most powerful influence of all these. It will be necessary for educators to develop ways of taking advantage of home computers and of developing cooperative relationships with parents in acquisition of hardware and courseware.

Home computers raise another important issue for the Nation—that of equity. Not every home will have computers. We must develop ways of ensuring equality of access across socioeconomic boundaries.

Promising Future Directions

The conferees identified several application areas for computers, including: "intelligent" drill-and-practice; simulations as developers of procedural skills; embedded and adaptive testing; computer-controlled video discs; and computers as intellectual tools.

Problem areas identified included: identification of new school structures to accommodate the new technologies; development of incentives for creative developers; and recruitment of courseware authors.

Major Recommendations

The conferees compiled a list of 28 recommendations for the Commission. Of these, the following are the most important:

1. Overall, the conferees see an important role for technology in enriching the educational experiences of all children, and urge the Commission to endorse vigorous pursuit of its application to the improvement of education at all levels.
2. The most critical need is to train teachers, administrators, *and* parents in the uses of technology in the education of children.
3. The conferees urge the Commission to support the Downey Bill (H.R. 1134) to provide the support structures educators need.
4. The Nation must find ways of providing equality of access to the advantages of technology to all children.
5. The Federal Government has a crucial role in establishing educational technology. This includes investing venture capital in development, coordination among the states, and establishing long-term evaluation programs.
6. Business and the military benefit from the products of our educational system, but must invest in overcoming its deficiencies when they exist. Ways must be found to bring these two groups into the development

program along with the Federal and state governments, and the educational system.

I. INTRODUCTION

At the request of the Commission on Precollege Education in Mathematics, Science, and Technology, a conference was held at the New York Institute of Technology on April 24 and 25, 1983. The broad purpose of the conference was to prepare a set of recommendations for the Commission that would contribute to the achievement of its goals. The list of attendees and others who contributed to the development of the conference are listed in Appendix A.

The conferees considered six major topics during the meeting:

1. Definition of educational technology (in the broadest terms) and its sphere of application in education in mathematics, science, and technology.
2. Gathering of evidence of the effectiveness of educational technology.
3. Identification of examples of high-quality courseware.
4. Promising future directions for the development of applications of technology in education.
5. Identification of nonschool environments in which educational technology can contribute to the education of children in mathematics, science, and technology.
6. Identification of the responsibilities of the several elements of our society in developing the potential of educational technology.

Before we consider specific recommendations, there are several general observations that should be made:

1. Educational technology is not considered by the conferees to be a panacea for all the problems of our educational system, but it can contribute significantly to its improvement.
2. The book was born in the fifteenth century, but did not impact the education of the masses until the nineteenth century. Even then, it penetrated very slowly. We had a great deal of time to develop a structure within which to use the book.

   Technology, on the other hand, has played a serious role in education only within the past three decades, and the computer only for the past two. The pace of development has been breath-taking and has occurred so rapidly that there has been little time to assimilate technology into the system. This pace (an accelerating one) must be considered in any plans to take advantage of educational technology. Toffler's *Future Shock* is nowhere more evident than in education.
3. Computers are entering our homes at a rapid rate. For good or ill, their existence will have an impact on our educational system.

4. There is an increasing gulf between the "haves" and the "have nots" in access to technology. This gulf must be minimized in any comprehensive plan for improving our educational system.
5. Many people still think of computers in the same way now as they did in 1968. New capabilities require new thinking!
6. The educational establishment (teachers and administrators alike) resist change with great vigor. Waterman, for example, developed the fountain pen in 1880—yet, in the late 1950s, there still were schools which used ink wells and dip pens! Such conservatism must be overcome if innovative techniques are to survive in the system.

II. EDUCATIONAL TECHNOLOGY—DEFINITION AND DOMAIN

A. Definition

Educational technology, as a term, must be defined if we are to discuss how educational technology can help our students to improve their understanding of mathematics, science and technology.

We propose the following definition:

> "Educational technology is any technology that is used to create or improve learning environments."

There are a number of technologies that have been used within this context. They include:

1. Computers which are the currently dominant technology in education. We include here both microcomputers and main-frame computers—although, as the capabilities of microcomputers increase, the distinctions between the two will blur.
2. Television. Even though it has been characterized as a "wasteland," it has been used effectively in many circumstances.
3. Satellite communication systems that permit delivery of educational materials to large numbers of people over widely scattered areas. It is especially important in sparsely settled regions.
4. Telecommunications is a relative newcomer to educational technology, but holds a great deal of promise, especially in distance-learning situations.
5. The videodisc is a relatively new, but potentially very valuable technology in education. It has similarities to television, but there also are important distinctions between the two that must be made.
6. Intelligent videodisc systems, the term coined by Dr. Alfred Bork, are used to identify systems in which microcomputers and videodisc systems are combined to create powerful learning environments.
7. Videotex and database systems are also important technologies.

B. The Computer

The computer is the most versatile of the technologies identified in Section A. It has the distinction compared to other technologies that it is a highly interactive medium. We shall describe briefly here the ways in which computers have been used to create learning environments:

1. Learning About Computers

Probably the widest use of the computer in our schools is in teaching programming. This application is important for several reasons:

a. Programming ability is a marketable skill. Many jobs in the future will require some level of skill at programming.

b. It encourages students to think algorithmically and develops problem-solving skills.

c. It strengthens intellectual development of the learner.

d. The process has been likened to teaching. Many teachers are aware that to really learn a subject one must teach it. Programming a computer is similar to "teaching" the computer how to solve the problem being addressed. The process requires that the student (i.e., the "teacher") understand the subject and the solution technique.

e. Learning programming develops procedural thinking skills––skills that are important in our society, but that are poorly developed in most school settings.

2. Learning Through Computers

The major focus of research and development in educational computing (measured in effort and dollars spent) has been on drill-and-practice, diagnostic testing, and question-and-answer tutorials. This mode of computer use has several attractions:

a. There is a body of research attesting to the effectiveness of this mode of learning compared to conventional instruction.

b. Its familiarity to teachers, administrators, and the public make it easy to assimilate into the system.

c. With authoring languages like PILOT, teachers are able to develop their own learning materials with relative ease, permitting them to tailor the material to the needs of their students and giving them the feeling of control and "ownership."

d. The cost of developing materials in this mode is moderate.

e. Because it involves a one-on-one relation between the student and the computer and because there is little need for teacher intervention during a lesson, this mode is well-suited to home-based learning.

f. It permits each student to learn at her/his own pace.

One caution is in order at this point. Learning through the computer is a computer-controlled learning mode as compared with learning with the computer as described in the next section. Concerns have been expressed that, in our pluralistic society, poor children will learn under the control of the computer, while those in well-to-do areas will learn to control computers. This does not mean that this mode is not useful in fostering learning; however, it must be used carefully as a part of a total approach in every school system.

3. Learning with Computers

The most promising use of computers in learning environments, both formal and informal, is the use of the computer as a tool of instruction and an environment within which learning can occur.

This mode is the least developed of the three because it is the most sophisticated and, hence, the most difficult to implement, but it appears likely that it will be the most important area in the future.

Materials generated for this mode generally are more expensive to produce because they require a wide range of talents and expertise not found in a single individual; however, they offer rich opportunities for learning of concepts and procedural skills, as well as development of the student's intellect.

This mode has several components, including:

a. Microworlds are cybernetic environments within which elements may be combined according to given rules. These environments permit students free rein to experiment with the environment, building a "microworld" and learning about the consequences of the rules, and developing problem-solving skills.

b. Educational games take advantage of the interest most of us have in games to generate exciting learning environments. Sometimes games are an environment for a drill-and-practice session, which makes that session more interesting for the student and, thus, increases student motivation to learn. Sometimes the game creates learning environments that are difficult or impossible to create otherwise.

   A largely unexplored example of the latter case is the adventure game in which the student is placed in a situation that requires exploration of the environment (frequently a cave, a castle, or forest), experimentation, problem solving, and decisionmaking. In addition, the student develops reading and comprehension skills. Few currently available adventure games are designed with learning as the principal objective. Once their potential is uncovered, they will provide rich learning experiences for students. Even the ones that currently are available provide such experiences, even though they were not designed with that purpose in the mind of the designer.

c. Microcomputer-based instrumentation (in which the computer is connected to the real world through any one of a variety of transducers and serves as a data gatherer and processor and as a display generator) permits students to explore real-world phenomena without being overwhelmed by the drudgery often associated with laboratory experiments. Students in these situations will be better able to discover underlying principles. Such an approach permits students to conduct experiments at a much earlier age than usually is the case.

d. Databases that may be accessed by the student through a computer and manipulated by the student with the assistance of the computer provide a totally new resource to learning. Already, hundreds of data bases exist for professionals in many fields. Once students are given access to these databases, as well as to others especially designed with students in mind, they will be able to carry out powerful investigations in many disciplines.

e. The computer is a powerful tool for the teacher and for the student in the study of a variety of disciplines. There are software packages, for example, that plot graphs of functions specified by the user so that relationships and properties of these functions may be visualized easily. Because of its computational power and speed, the computer allows on-line, interactive displays to be generated without the drudgery usually involved in such activities. With these tools, it is possible to ask students to explore much larger numbers of functions than is reasonable by hand.

Other exciting tools available to educators and students include:

I. Word processing, which has been found to generate dramatic improvements in students' writing skills and attitudes toward writing, is being used by innovative science teachers who require their students to write laboratory reports and to produce science newsletters.

II. Spread-sheet programs, which were designed originally for accounting and business-projection purposes, but which are useful also as general-purpose simulation tools for the study of population-dynamics, economic systems, and a wide variety of other dynamic systems.

III. General-purpose problem-solvers, which permit students to study phenomena for which they are ready intellectually, but for which they do not have adequate mathematical preparation.

f. Newer, special-purpose computer languages are becoming available that permit students to develop their skills in many ways not previously available. Among these are: LOGO, which is a learning environment as well as a language; TUTSIM and Dynamo, which are simulation languages that make it easy for the user to create her/his own simulations; and GraFORTH.

We can expect the introduction of many additional special-purpose languages to address needs that we perceive only dimly.

g. One of the most versatile applications of the computer is as a simulator of real-world phenomena. In this mode, the computer serves as a flexible universe within which any environment the teacher desires can be created. Systems that are inaccessible to the student because of danger, equipment cost, complexity, time scale, or experimental skill requirements become accessible.

h. Discovery learning in mathematics is a potentially fruitful, but largely unexplored application of computers. In this mode, the computer serves as a laboratory environment within which the learner can discover the concepts in mathematics that are important. Concepts like limiting processes, slope, maximum and minimum, functions, addition, and subtraction of positive and negative numbers, roots of equations (to cite just a few) are understandable to students over a wide range of mathematical abilities.

C. Educational Television

When most people think of using television for education, they think in terms of commercial TV and are appalled by the thought. This is the commonly-held view that TV is a "wasteland." In fact, viewed correctly, TV can make significant contributions to the education of our children.

"Sesame Street," "3-2-1 Contact," and the "NOVA" series on PBS are just a few examples of outstanding TV-based materials which are available to educators.

Many colleges and universities in the U.S. are offering courses via TV (either broadcast or using video tape) to groups of adults, who for one reason or another, do not take courses in the normal classroom mode. According to a recently-quoted Roper study, "30 million adults say they can't find the time for formal studies and are willing to take college credit courses on television and to pay for them." As a result, PBS has formed an organization called Adult Learning Service to address this need.

TV Ontario has conducted extensive research and development on educational applications of TV. Among the applications they have identified are:

1. The development of "lots of good stories to develop a wide range of comprehensive skills."
2. Development of problem-solving skills in three-to-six-year-olds through a series called "Today's Special."
3. Development of vocabulary and reading skills in fourth and fifth graders through a series called "Read All About It."
4. Teaching of concepts of physics to middle-school children through a program entitled "Eureka!"
5. Teaching of geography in the middle schools using a series called "North America: Growth of a Continent."

6. Captioned TV programs for deaf and hearing-impaired students.
7. Improving skill in a foreign language.

All of these courses were designed to be used in the classroom as well as in the broadcast mode at home. In each case, the TV series was supplemented by teacher and student booklets.

During the Summer of 1983, PBS will be running a series called "Reading Rainbow" using well-known TV personalities reading some of the best books in literature for children. The series is aimed at six-to-nine-year-olds.

Television has been used successfully since 1964 (when the University of Florida started delivering graduate electrical-engineering course work to engineers at Cape Kennedy) to deliver graduate instruction in engineering. Successful live microwave delivery of instruction is being carried out at, e.g., Stanford University, Purdue University, and Illinois Institute of Technology; while videotape is being used at, e.g., Colorado State University, University of Arizona, Georgia Institute of Technology, and the University of Idaho.

It is clear that production of a high-quality educational TV series is expensive, and requires spreading the cost over large groups of students; however, there is no doubt that TV, properly applied, can provide a rich variety of learning experiences which are unavailable to students through more conventional means (textbooks and lectures). This is especially true in elementary school and middle school science courses.

E. Videotex, Databases, and Computer-Based Telecommunication

Videotex and computer-based telecommunication are techniques that use the same technology, but in very different ways. Both consist essentially of a large central computer that may be accessed from any one of a large number of remotely located microcomputers or computer terminals. In both cases, the user at her/his terminal interacts with the central computer—this interaction is a central feature of the system, in both cases. The two systems differ significantly in the character of the interaction between users and the central computer. Both systems have great potential for education, and both will be described briefly in the paragraphs below:

1. Videotex

The essential features of a videotex system are the availability to the user of a wide variety of databases and the intimacy of the interaction between the user and those databases.

Typical of commercially-available videotex systems are CompuServe and The Source. In these systems, the user may access databases containing information on: financial matters, current news items in great depth, legislative matters at state and federal levels, demographic data, consumer-oriented "catalogs," and on a great variety of scientific disciplines. One can imagine that the videotex system will replace the encyclopedia as the information source of the future for students at all levels. It has the enormous advantage, over printed encyclopedias, that it can be kept current on a moment-by-moment basis.

2. Computer-Based Telecommunication

Computer-based telecommunication, although similar to videotex in the hardware that it uses, is very different conceptually from videotex. In this mode, the computer serves principally as a communications channel between two people, or among the members of a company, members of professional organizations, teachers, administrators, etc.

The power and storage capacity of the computer are used to facilitate and enhance the intercommunication that goes on among the participants. The power of the computer is used to permit the users to do on-line editing through resident word processors and to do filing and retrieving of information in complex and flexible ways.

The storage capacity of modern computers permits intercommunication among the members of a group in an asynchronous manner, i.e., two people who wish to discuss some matter may do so even if they are not at the communication system at the same time. In that sense, telecommunication is similar to communication by mail, although the transmission time of a message is measured in seconds rather than in days, and access and retrieval of information is dramatically easier.

Telecommunication systems are potentially useful in education because they permit "education at a distance." New York Institute of Technology, for example, offers several courses in which telecommunication is an important component to students whose schedules do not permit them to come to the campus for conventional classes. The students and instructor are linked together through the school's telecommunication system and discuss points that need clarification, as well as administrative aspects of the course. In addition, the instructor is able to transmit new information to the class as it is generated, as well as to share with the entire class the work of a student who has done a noteworthy paper.

Such a vehicle has clear implications for educational situations wherever students cannot attend classes in a central location. There are at least two classes of circumstances where this is the case: in sparsely populated areas of the United States where it is economically difficult to bring students to the teacher; and in disciplines where there are few experts. In the latter application, the expertise that exists can be made available to people over an unlimited geographical region. The training of teachers in uses of the various educational technologies and in modern aspects of their disciplines is one important example of remote instruction by telecommunication at a cost that is within reason.

An example of this approach to teacher education was cited in a recent issue (April 25, 1983) of the *Department of Education Weekly.* A university professor in Iowa is conducting a course for high school physics teachers who participate in their own school laboratories. The professor communicates with the teachers through a telecommunication system. The implementation is costing the State of Iowa $30,000 this year for all hardware and materials costs for 45 schools. Next year it is expected that every high school in the State will be connected to the system.

F. Videodisc Systems

A videodisc usually is thought of as a new medium for presenting television programs, and it certainly is that; however, it is much more. A single videodisc contains 54,000 frames. These frames can consist of half an hour of motion sequences, over 54,000 individual still frames (e.g., 54,000 slides of biolgical specimens), or any combination of motion and still frames. It also is possible to run frames in slow or fast motion, if that is desirable pedagogically. In addition, it is possible to access any frame at random within a few seconds.

The combination of these properties provides the instructional designer with the opportunity to create a rich environment for the learner.

Despite this potential, the videodisc has not yet penetrated into the educational system because videodisc players still are relatively expensive and because the production of videodisc programs still is quite difficult.

Fortunately, these things are changing. As videodisc players become more popular with the consumer, their price will drop to the point where they will be affordable by schools, and we can expect that, soon, writeable videodiscs and inexpensive disc recorders will become available. In the interim, several groups in the United States are developing demonstration discs to explore the medium.

G. Intelligent Videodisc Systems

Intelligent videodisc systems involve the combination of the strengths of videodisc systems and those of microcomputers and, in this combination, they overcome some of the weaknesses of each.

Videodisc systems permit the display of high-resolution graphic images at moderate cost, but have the drawback that the available images are fixed in the medium (the available images have been preselected by the producer of the disc). The computer, on the other hand, can produce images that respond to the needs and wishes of the user, but those images have only limited resolution. In addition, video-disc images are available almost instantaneously, whereas computer-generated ones take a significant, and sometimes educationally-intolerable, time to generate.

Computers have very powerful decisionmaking abilities inherent in their structure, whereas videodisc systems have no decision-making ability. By combining these technologies, the strengths of each can compensate for the weaknesses of the other to provide an educational environment for the student which is very rich.

A learning environment that combines the capabilities of both computers and videodisc systems has been called by Dr. Bork of UC Irvine an intelligent videodisc system. Such systems can provide students with simulations of enormous power and flexibility. It is possible to conceive of an environment where a student carries out, for example, a simulation of an ecological study in which the videodisc component provides images of the flora and fauna at many locations in a river whose pollution is being studied. The student can look at pictures of a species of organism under a microscope and compare those from one location with those from another. By transferring to a computer simulation, the student can investigate the level of pollution as a function of dumping levels and treatment technique and then, with the help of the computer, can go to the section of the video disc on which images of flora and fauna are shown that exist under the circumstances the simulation has generated.

Little work has been done yet to exploit the potential of intelligent videodisc systems, principally because videodisc systems themselves have not yet become widely available to schools; however, a few examples of what has been generated are:

1. The Minnesota Educational Computing Consortium (MECC) economic courses produced by Dr. Richard Pollak.
2. The WICAT biology disc produced for McGraw-Hill.
3. The package produced by Quentin Carr at the Herkimer, New York BOCES on weather instruction.
4. The cardiopulmonary resuscitation program developed by David Hon, which may help to solve the problem of woefully inadequate numbers of CPR instructors which currently exists.

H. Robotics

Robotics is a field usually associated with industry and automation. We suggest here that there are circumstances in which robots may be useful in educational settings.

One such application of robots which has gained in popularity along with the increasing popularity of the LOGO language is the Milton Bradley Big Trak "toy." In its conception, Big Trak was indeed a toy; however, imaginative teachers looking for a way to make the LOGO screen and its turtle graphics more concrete and, hence, more comprehensible to their young students, saw in Big Trak a real-world implementation of the LOGO turtle. Big Trak is a tank with a built-in microcomputer which can be programmed by young children to maneuver over a predefined course—in other words, it is a simple robot, programmable by children!

Advertisements are beginning to appear offering robots which cost only about $1,000—not cheap, but beginning to approach the range of affordability to schools. Such robots, in the hands of imaginative teachers, can provide strongly-motivating experiences for high-school students, and can prepare them for exciting industrial careers.

I. Conclusion

The technologies described in the foregoing paragraphs represent only those which currently are in use. They are only the leading edge of the technological revolution which we are about to witness. Among the technologies which we now can predict are:

1. Cellular radio in which local radio stations are linked together to cover large geographic areas.
2. Fiber-optic based communications links which will cut communication costs dramatically.

3. Enormously increased information storage and retrieval capabilities. NASA expects, by June 1984, to have available an optical disc storage-and-retrieval system with a capacity of 10 million bits (10,000 times that of most current computer systems!). With this system, it is expected that users will be able to access all the information on line.
4. Within two decades, we can expect satellite firms to provide 22,000–48,000 channels for video, voice, and other communications.
5. There have been predictions that within a decade, most homes will be wired for two-way communications in much the way of many homes in Columbus, Ohio with its Qube System.
6. Low-power TV stations will serve specialized audiences.
7. It has been estimated that the cost of storage of information on disc dropped below that of paper storage in 1980, and that by 1990 it will be only one percent of the cost of paper storage. Such cost figures suggest dramatic changes in our perceptions of publications in general. Electronic publishing surely will follow such cost reductions.

Each of these technologies and others which have not yet emerged from the research laboratories will contribute to the improvement of education in ways we cannot yet perceive.

Yet another dimension of this picture of educational technology which must be considered is the design of systems which integrate the individual technologies into information systems which take advantage of the capabilities of each to create a whole which is much greater than the sum of its parts.

One exciting example of this (in addition to the intelligent video disc described above) is the major series on the human brain now in development at WNET/Thirteen, in which the producers are creating a college-level psychology course to be offered in association with airing, in 1984, of eight one-hour programs. The programs will be supplemented by a textbook being written by a group of leading scientists. In addition, a museum exhibit is planned for major cities that features an interactive videodisc that will enable visitors to explore regions of the brain. Excerpts from the series, including animated simulations of neural transmission, will be distributed to high schools along with associated explanatory materials and microcomputer software.

Clearly, the extent to which technology can contribute to the education of our children is limited only by our imaginations and our willingness to commit resources.

(The full report to the Commission also addressed the issues of effectiveness, quality courseware, informal learning centers and future directions.)

APPENDIX A

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6

RESEARCH ON COGNITION AND BEHAVIOR RELEVANT TO EDUCATION IN MATHEMATICS, SCIENCE,AND TECHNLOGY

Report from the Federation of Behavioral, Psychological and Cognitive Sciences

Prepared by James Greeno, ***University of Pittsburgh***

SUMMARY

This paper summarizes a report based on a hearing organized by the Federation of Behavioral, Psychological, and Cognitive Sciences for the National Science Board Commission on Precollege Education in Mathematics, Science and Technology. The purpose of the report is to provide the NSB Commission with information about recent advances in cognitive and behavioral science relevant to education in mathematics, science and technology, as well as prospective contributions from these fields if adequate levels of support are available. In this summary paper we discuss some of the major recent contributions and topics for further fruitful research that are considered in the full report.

The need for strengthening our nation's educational programs in mathematics, science, and technology is now recognized by almost everyone. Significant resources must be directed immediately to reducing the critical shortages of qualified teachers of mathematics and science in our elementary and secondary schools.

At the same time, some important problems cannot be solved by the use of current educational methods. A higher level of technical knowledge and skill is required for productive employment and for effective citizenship than in the past, and these demands still continue to increase. More effective teaching materials and methods are needed to provide students with knowledge and skill for problem solving and reasoning based on scientific, mathematical, and technological subject matter. Improved understanding of processes of problem solving, comprehension, learning, teaching and testing is needed to guide the development of new educational resources, including effective use of new computational technology.

American education has benefited in fundamental ways from basic research in behavioral and cognitive science. Important examples include behavioral task analysis that has been used in formulating objectives for instruction and testing, as well as psychometric methods used in developing and evaluating tests of ability and achievement. Research on these and other topics continues to provide important empirical and theoretical contributions to our understanding of educational processes. Recent scientific developments, especially in the analysis of cognitive processes, have special relevance for education in mathematics, science and technology. These developments in theory and methodology have provided significant new insights into students' processes of solving problems and understanding concepts. These findings provide significant opportunities for development of improved educational methods in mathematics and science. We are acquiring new capabilities, for instance, of diagnosing the *specific* gaps and errors in students' understanding of arithmetic procedures, and of providing individualized assistance to students to remedy those faults in their understanding. And we have developed knowledge, communicable to both teachers and students, that can help them grasp the vital distinction between rote learning and learning with understanding, and help students, as well, to monitor the depth of their own understanding of topics they are studying. Continued scientific investigation based on these recent findings promises to provide further important knowledge relevant to important educational questions.

We present brief summaries of some recent findings that illustrate the relevance of behavioral and cognitive research to education in mathematics, science, and technology.

An important topic in recent research has been processes and structures needed to use and understand formal materials *qualitatively*. At present, instruction in mathematics, science, and technology emphasizes quantitative procedures and formulas. Formal knowledge alone is inadequate if students are to be able to solve problems using their scientific or mathematical knowledge, or to achieve correct understanding of the principles represented by the formulas and procedures that they learn. Scientific study of problem solving, reasoning, and learning has provided important new information and theoretical understanding of the ways of thinking that are required for successful use and understanding of formal knowledge.

One form of qualitative cognition involves *knowledge used for understanding problems*. When students are required to solve problems that are presented with text and diagrams, they must construct representations in their minds of the information in the problems. We have learned much about knowledge structures needed to represent problems in physics, in elementary arithmetic, and in electronics; theoretical representations of these structures have been developed in the form of schemata and computer models. Research has begun to develop instructional methods that can increase students' skills in representing problem information, and we already know enough to aid teachers in discovering how adequate are these skills in individual students.

Another form of qualitative cognition involves *functional understanding* of procedures used in solving problems. Recent research has shown that general concepts and cognitive procedures can be integrated and mutually reinforcing, and ways in which such integrated knowledge can be produced in instruction are being investigated. In debates about computational skill and conceptual understanding such as those surrounding the "new math," skill and understanding have been considered as competing alternatives. In the view that is now emerging from research, there are general functional concepts and principles corresponding to critical relationships among components of task situations and the procedures that are used in the domain. Analyses of these functional principles have been provided in elementary arithmetic and high school geometry; these analyses have begun to show how understanding general concepts can facilitate learning and performance of correct procedures in addition to providing meaningful understanding of the procedures. An example is understanding how goals and subgoals can be generated in the process of searching for solutions to geometry problems.

Research in the domain of physics has shown that students begin with significant misconceptions of qualitative conceptions that they apply in understanding physical phenomena. Their intuitive ideas of falling bodies are more like those of Aristotle than those of Galileo. These tend to persist through instruction, so that their qualitative understanding of principles is inconsistent with the significant principles underlying the formulas they have learned. Instructional methods are being investigated designed to overcome these intuitive misconceptions.

Research also has identified factors that influence students in selecting courses in mathematics and science, particularly among young women and members of minority groups. In addition to achievement in previous educational experiences, individuals are more likely to continue their mathematics and science education if they perceive these fields to be relevant to careers that are available to them, and if they have general interest in "things," rather than primarily in "people." Contrary to some popular belief, exposure to female role models in science and mathematics has been found to have little effect on young women's decisions to obtain science and mathematics education.

Needs and Opportunities for Research

As we have just seen, results of recent research can be used now to guide development of new instructional materials and methods. In the body of this report, we supply examples of new ideas about how to help students build their interpretations of algebra word problems and physics text problems. We report advances that can improve teaching of place-values in arithmetic and help students overcome erroneous preconceptions in physics. We refer also to research that suggests approaches to diagnostic problem solving. Enough is known to provide a sound basis for design of instruction to provide improved skill in representing problem situations and stronger functional understanding of formal procedures and principles, and to take account of students' preconceptions and interests.

Research findings have shown that knowledge for understanding problems, functional understanding, and mental models are essential for effective learning and performance. Better understanding is needed of how these aspects of cognitive structure facilitate performance and learning.

A great deal is now understood about knowledge required for solving problems in individual domains, like those already mentioned, but there are significant unanswered questions about the kinds of cognitive structures and processes that enable knowledge acquired in one domain to be applied in another, for example, how knowledge of math is applied in physics. An important aspect of this question involves the nature of general skills for problem solving, reasoning, and learning, and whether cognitive skills with significant generality can be acquired through instruction. Analyses of transfer in some domains have shown that qualitative understanding of principles can provide a basis for significant transfer. Research is needed also to identify instructional materials that provide students with knowledge and skills that they require for productive employment and meaningful citizenship in an increasingly technological society. Progress has been made in understanding learning of basic components of problem-solving skills. We do not yet understand learning of strategic knowledge for representing problems, and procedural knowledge integrated with functional principles. Principles that are discovered in these studies of acquisition will be useful in designing instructional materials and methods of assessment, which also can take account of students' preconceptions and interests related to the subject matter, and exploit resources that are available because of advances in computational technology.

Structures for Support and Application

Recent developments have brought about a significant strengthening of America's resources for scientific research relevant to education in mathematics, science, and technology, as numerous scientists have turned their attention to processes of problem solving, reasoning, and learning the specific subject-matter materials of these fields. Research on problems relevant to education in mathematics, science, and technology benefits from close collaboration among behavioral and cognitive scientists, mathematicians and scientists in the fields being taught, and educators.

An important condition for application of research findings is their communication to teachers. Strong efforts should be made to include up-to-date scientific knowledge about cognitive and behavioral processes in inservice and preservice teacher training programs. Research programs in which classroom teachers participate as collaborative scientists can play an especially helpful role, both in informing the research effort by direct acquaintance with the teaching context and providing the occasion for participating teachers to become directly familiar with research methods and results.

FOREWORD

This report is based on materials presented at a hearing sponsored by the National Science Board Commission on Precollege Education in Mathematics, Science and Technology, held at Pittsburgh on 19–20 December 1982. The hearing was organized by the Federation of Behavioral, Psychological, and Cognitive Sciences at the invitation of the Commission. The following individuals participated in the hearing;

John Anderson, Carnegie-Mellon University
Thomas Carpenter, University of Wisconsin
Audrey Champagne, University of Pittsburgh
Susan Chipman, National Institute of Education
John Clement, University of Massachusetts
Nancy Cole, University of Pittsburgh
Ralph Dusek, Federation of Behavioral, Psychological, and Cognitive Sciences
Dedre Gentner, Bolt Beranek and Newman, Inc.

Robert Glaser, University of Pittsburgh
Andrew Gleason, Harvard University
Bert Green, Johns Hopkins University
James Greeno, University of Pittsburgh
Stanley Helgeson, Ohio State University
Jeremy Kilpatrick, University of Georgia
Leopold Klopfer, University of Pittsburgh
Alma Lantz, ESR Associates
Alan Lesgold, University of Pittsburgh
John Lochhead, University of Massachusetts
Erik McWilliams, CRT Corporation
James Minstrell, Mercer Island High School
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Mary Budd Rowe, University of Florida
Karen Sheingold, Bank Street College of Education
Alan Schoenfeld, University of Rochester
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Wayne Welch, University of Minnesota
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Additional materials for the report were provided by the following individuals:

John Scely Brown, Xerox Corporation
Jill Larkin, Carnegie-Mellon University
James Levin, University of California-San Diego
Frederick Reif, University of California-Berkeley

The report was drafted by James Greeno, Robert Glaser, and Allen Newell.

I. INTRODUCTION

The nature and purposes of education in mathematics, science, and technology are undergoing significant change. All children and youth, and an increasing number of adults in our country, now face educational requirements that demand previously unanticipated forms of competence. The level of knowledge and skill expected of individuals has risen sharply as a result of the demands of technological change for new knowledge and skill. In view of these changes, there may now be diminishing returns in continuing to employ the curricula and school practices that have effectively increased general educational levels in the past.

Toward the solution of this critical problem, we discuss contributions that past and forthcoming research in cognitive and behavioral science make to education in mathematics, science, and technology. We describe recent research findings that have important implications for the design and practice of education in these fields. We also discuss research questions that have strong potential for providing important further empirical and theoretical advances relevant to the improvement of educational practice.

A major recent scientific development is the growth of cognitive science, an interdisciplinary field that includes components of psychology, computer science, linguistics, anthropology, and education. It is important to emphasize that the development of cognitive science in the United States is substantially more advanced than in any other country. This provides an opportunity for American education in mathematics, science, and technology to utilize a set of findings for which American scientists have deep understanding, and to benefit further from research advances that can be achieved in the immediate future.

The considerable progress made recently in the cognitive sciences provides powerful new concepts and methods for approaching educational tasks in more systematic and scientifically principled ways.

The central scientific advance has been development of the capability to analyze the cognitive requirements for successful performance in complex intellectual tasks. This has been accelerated by new techniques that specify hypotheses about cognitive processes and knowledge structures that are the basis for successful human performance in the form of computer programs. This helps ensure that theoretical descriptions reach a level of detail that is adequate to explain performance and to provide guidance for instructional design.

The important outcome is an improved capability for analyzing students' understanding of concepts and principles of mathematics, science, and technology and to relate their understanding to their ability to perform successfully in instructional tasks. This has led to new insights into the educational effects of such issues as meaningful vs. rote learning and the importance of well-structured knowledge in acquiring new cognitive skills. These developments provide a considerable advance beyond earlier research and development in psychology and education. Specific analyses of cognitive processes and knowledge structures have been used to compare the knowledge and skills of experts with those of beginning students, providing a basis for more definite and useful specification of objectives for instruction. Analyses of students' knowledge prior to instruction and of errorful procedures and misconceptions that result from some instruction have provided new understanding of sources of students' difficulty in acquiring cognitive skills and knowledge.

Our scientific capabilities now enable us to analyze knowledge that is required for success in tasks used in mathematical, scientific, and technical instruction. Examples of subject-matter domains in which specific cognitive task analyses have been contributed include elementary arithmetic, algebra, high school geometry, mechanics, hydrostatics, and elementary electricity/electronics. We will describe results of some of these studies in Chapter II of this report. It is important to note that a substantial number of scientists are now studying these topics, providing a valuable resource of talent and experience for continued research and scientific training.

Most previous efforts at improving science education in the United States were directed at curriculum development together with some associated teacher training. In particular, the various major curriculum development projects of the

the 1960's attempted to introduce into schools points of view and conceptual approaches reflecting those of expert scientists or mathematicians. Although these efforts were laudable and partially successful, their ultimate educational impact and effectiveness were far less than had been hoped. One of the principal reasons for this failure was that the educational reformers focused their attention almost exclusively on curriculum content, thereby failing to pay adequate attention to important psychological aspects, the underlying thought and learning processes of students or experts and underlying social-psychological processes in the classroom. Our scientific capabilities for investigating these psychological processes have been greatly strengthened by the recent conceptual and methodological advances in cognitive science.

In the past, educational methods and materials based on fundamental research in behavioral and cognitive psychology have had profound effects on American education. The use of standardized tests, both for assessment of students' learning achievement and for selection for college and professional training, is based on psychometric methodology developed in psychological research that began early in this century. Principles of behavioral task analysis, based on fundamental research on learning and conditioning, have been used in formulating educational objectives, and have had strong influence on the design of instructional materials and tests. Rigorous application of such principles in the early grades is now producing heartening improvements in the school achievement of many inner city students. Little of education in this country has been untouched by these earlier scientific developments.

Research on many topics of behavioral and cognitive science, as well as other fields, continues to provide significant findings of importance for educational practice. In this report, we discuss a subset of the important research that has been done, focusing on studies that have dealt directly with processes of thinking and learning in the domains of mathematics, science, and technology. It is important to keep in mind that science is an ongoing process, so that important aspects of our current understanding will undoubtedly be replaced by concepts and principles yet to be discovered. Furthermore, any domain involving application of theoretical principles and scientific knowledge always involves a balance of current theory with practical wisdom. Even so, the potential for strengthening American education on the basis of past and prospective research in cognitive and behavioral science is strong.

I.A.Some Problems of Education

Our presentation of research findings and questions in Chapters II and III is organized by two major types of problems that face our educational system in regard to mathematics, science, and technology. First, there are problems of educational content: what to teach students so they can be effective in solving problems and reasoning about significant issues; what to teach about technology; and the role of basic mathematical and programming skills in the curriculum. Second, there are problems of increasing the participation of students in programs of mathematical, scientific, and technological education, and of increasing the effectiveness of the use of technological resources, including educational testing.

I.A.1. *Questions of Educational Content*. A major goal of education is to provide mathematical, scientific, and technological literacy. Students should acquire the ability to solve problems and reason effectively in a broad range of situations that arise in their lives and work. *The relevant question is whether the knowledge and skill that students acquire in the present curriculum provide as strong a basis as possible for general problem solving and reasoning.*

Students in mathematics and science often learn computational procedures and formulas that they are unable to apply in solving problems or in reasoning about qualitative questions. Recent research has provided improved understanding of the cognitive requirements of successful problem solving and reasoning in a variety of academic and practical domains, and these findings indicate a need to emphasize some aspects of knowledge not now emphasized in mathematics and science instruction.

The growing role of technology, especially computational systems, in human affairs implies a critical need for education that prepares students to understand and use technological resources. Recent research has provided information about properties of knowledge required for understanding technical systems such as electronic devices and power plants, and these findings suggest important issues for the development of education for technology.

The role of "basic skills" such as computational procedures in mathematics and interpretation of experimental data in science, is a question of long standing in the design of instruction, and computer programming is emerging as another skill that many believe all students should acquire. Results of recent research have advanced our scientific understanding of the kinds of conceptual knowledge and knowledge for representing problem situations that facilitate students' learning of correct procedures and their ability to use their formal knowledge in solving problems and reasoning.

I.A.2. *Questions of Participation and Effectiveness*. Economic and technological changes in the society are producing an increased need for individuals whose basic education in mathematics and science prepares them for advanced training in technologically demanding fields. A relatively high level of technological literacy is needed for successful performance in a great many work environments, and for informed participation in the formation of public opinion on critical policy issues. *We need improved methods of education to enlarge the group of students who learn mathematical, scientific, and technical subjects successfully.*

Recent research findings provide significant new information about sources of difficulty in learning and understanding mathematical, scientific, and technical concepts, and thus provide a basis for educational materials and methods that can reach a broader group of students. Research has also begun to identify factors contributing to relatively low levels of participation in mathematics and science courses by women and members of minority groups, and thus suggests ways in which increased participation by those individuals, and indeed all persons, can be encouraged.

The potential impact of new information technology on education is widely recognized, as is the need for research and development to enable its beneficial use. This is especially significant for education in mathematics, science, and technology, where the need to provide soundly based computer-augmented instruction is becoming critical. Cognitive and motivational properties of computer-based instructional systems have been studied in recent research, and the findings provide guidance for the design of instruction with computers and other media.

Data in the form of test scores are an important source of information about the success of our educational programs, and they play an important role in assessing individual student achievement and selecting individuals who are most likely to succeed in advanced and specialized training. The design of tests is influenced strongly by theories of the cognitive abilities or knowledge that is being assessed, and recent research has provided advances in our understanding of the characteristics of general and specific cognitive skills that effectively indicate successful performance on tests of achievement and aptitude. Tests also have a considerable influence on the shaping of instructional content; thus, it is important that new understanding of instructional goals should be reflected in new approaches to testing.

I.B. Introductory Examples

We present a set of research findings that have been obtained recently, primarily in the last five years. These findings, their implication for education in mathematics, science and technology, and some prospective research to build on present knowledge, are discussed here to illustrate the kinds of results and conclusions that are characteristic of recent research. In Chapters II and III we provide a survey of research topics and findings in which the discussion of each topic is very brief; if more specific discussions were provided, they would be comparable to the discussion presented here.

The example research that we discuss here focuses on a common theme of *qualitative understanding*. Much of the knowledge currently taught in mathematics, physics, and technology is based on quantitative, analytic principles of the domains. These formal principles act as a set of constraints that characterize *what happens* in a system. Almost by definition, such a characterization provides students with little understanding of the underlying qualitative mechanisms governing *how* it happens. Said differently, students fail to learn how the formal constraints are necessarily satisfied or even how the requisite behavior emerges from these constraints.

The elegant and concise formal description of diverse and complex phenomena and the use of rigorous systems of deductive inference are major intellectual accomplishments of science. Not surprisingly, they are displayed and emphasized in the curriculum. However, it is now widely understood that *formal knowledge of mathematics and science is not sufficient in itself for effective use of the knowledge or for intellectual work that advances the fields of knowledge*. Scientists, mathematicians, engineers, and technical workers commonly recognize that their "textbook" knowledge must be supplemented in significant ways for them to be effective in their work. The characteristics of the additional knowledge and skill needed for effective work have not been understood, beyond the truism that they are probably acquired in practical experience, rather than in formal instruction. (It could hardly be otherwise, since the additional knowledge and skill are just those necessary cognitive components that are omitted from formal instruction.)

In recent research, several findings have been obtained that provide significant new insight into knowledge and skill that involve qualitative principles in mathematics, science, and technology. With these findings, we can begin to specify the characteristics of qualitative understanding in definite ways, and to specify the ways in which that understanding functions in problem solving, reasoning, and learning.

A key idea that has emerged from this work is that *knowledge of qualitative principles enables an individual to construct mental models of how a system or a procedure "works."* These models, in turn, form the bridge with much of the individual's common-sense understanding of the world, in both physical and social aspects. But these mental models do more. For the theoretically inclined student, this kind of knowledge provides the basis for guiding his or her intuitions concerning how to construct precise mathematical models of a given phenomenon, as well as how to make sound approximations in *solving* the equations comprising the analytic models.

For technicians or maintenance personnel, these qualitative, causal models provide the basis for formulating defensible hypotheses for explaining observed malfunctions of a system or a machine. This kind of knowledge enables the technician to construct simulations "in the mind's eye" of how a system functions and to use the constructed causal models to guide his or her common-sense reasoning and troubleshooting strategies. That is to say, with such models, the individual can develop a generic understanding of systems and use this understanding to handle novel problems and enable his or her troubleshooting methods to be more than just rote procedures.

Research advances have been accomplished in two areas: the role of qualititative understanding in problem solving, and its role in learning.

I.B.1. *Qualitative understanding in problem solving*. Research investigating the detailed nature of problem solving in several domains has provided significant new information about the cognitive processes and knowledge that are needed to *use* the formal knowledge of science and mathematics. Typically, in mathematics and science teaching, formulas and computational procedures are explained directly, but use of those formal procedures for solving problems is treated implicitly, using examples but little or no direct instruction about problem-solving methods. Recent findings have shown some of the kinds of knowledge that are required for successful problem solving, and have provided explicit descriptions of that knowledge relevant to selected domains in mathematics and science. As we develop explicit characterizations of knowledge required for problem solving, it will become possible to provide instruction that trains that knowledge more directly and, as a result, we should expect greater effectiveness in teaching problem-solving capabilities.

Arithmetic word problems. Knowledge required to solve simple arithmetic word problems has been studied in detail, and a complete analysis is available for problems that are solved with addition and subtraction. To solve these

123

problems, students must form intermediate representations that include relationships among the quantities in the problems. To form these representations, students must learn to recognize three distinct patterns that involve different ways in which quantities can be related. These patterns correspond to groupings of problems that are fundamentally the same beneath their varying surface details. The technical term for such underlying patterns is schemata. For simple arithmetic problems, these underlying patterns have now been identified and described. One of these, a Change pattern, involves an event that increases or decreases the value of some quantity. A second pattern, Combination, involves two quantities that do not change, but are considered both separately and in combination. The third pattern, Comparison, involves two quantities and the difference between them. Models of the problem-solving process have been formulated to show how recognition of these patterns is needed, and depends on knowledge in the form of *schemata*, cognitive structures that include the relationships in general form. The models have been tested in detailed observations of performance of children as they solve problems, and have provided explanations of different levels of skill that are observed among elementary school children.

Physics text problems. Several investigators have conducted research on processes of solving text problems in physics. A detailed analysis has been formulated as a simulation model for solving statics problems. Knowledge that is required includes schemata for representing relevant quantities and their relations in problem situations; for example, to solve a problem about a man standing on a ladder leaning against a wall, the representation can be formed by assembling a wall schema (surface), a floor schema (surface), a ladder schema (lever), and a man schema (mass), assigning to each component appropriate numerical quantities and appropriate connections with the others. Research also has been conducted in the domain of elementary electronics, and it was found that a major source of difficulty in solving course problems was due to inadequate acquisition of knowledge for representing problems including general relations among quantities.

In addition to specialized knowledge about physics problem situations, problem solving requires use of general causal knowledge about motion of objects and other physical factors. Solution of problems in kinematics has been analyzed, and often includes representation that uses a "mental model" of the objects and surfaces in the problem to determine the set of variables and formulas that have to be used to obtain the solution.

Research findings have been obtained regarding the knowledge used by expert physicists in solving text problems, compared with the knowledge used by successful students with a year or two of study. The problem representations constructed by experts are based on knowledge that is organized by abstract physics concepts and principles, such as the conservation of energy, that furnish the representations for general methods of problem solution. Students' representations are based on more concrete features of problems, showing that their knowledge of general principles is not yet integrated with their problem-solving knowledge.

Implications for education. With more specific scientific understanding of the knowledge required for successful problem solving, instructional methods can be designed to *more effectively provide students with knowledge for problem solving.* Materials for modifying and expanding the student's approach to representing problems have been developed and are being tested in current research. Materials for teaching kindergarten children to represent some of the relationships found in word problems have been designed and tested as a means of increasing their readiness for primary grade mathematics. Authors of at least one elementary mathematics text series are currently considering ways to incorporate results of research on word problem representation in their instructional materials.

Further research needs and opportunities. The methods and results of research on problem solving in simple mechanics and elementary mathematics can be used to provide comparable analyses of knowledge required for problem solving in other domains. This constitutes an important area of applied research, to provide a basis for development of specific teaching materials for strengthening students' problem solving skills.

Fundamental as well as applied research is needed to investigate *processes of acquiring skills in problem solving*, including the knowledge for representing problems that have already been identified. Theoretical analysis of learning processes is a major current research topic in cognitive science, and analysis of the acquisition of the knowledge required for representing problems would provide important new theoretical advances as well as information of great practical importance for education. Investigation of fundamental properties of learning necessitates development of experimental instruction to provide the learning experiences to be studied. The materials developed for these experiments will contribute to development and evaluation of instructional materials, which will provide new resources for teaching problem-solving skills.

A major unanswered question is the nature of *knowledge that enables transfer of skills* acquired for solving problems in one domain to capabilities for solving problems in another domain. Some preliminary findings have been obtained, involving use of general conceptual structures and processes of forming analogical mappings between the domains, but considerable further investigation is needed to provide adequate scientific understanding of this important cognitive question.

I.B.2. *Qualitative understanding in learning.* Research findings have provided important new information about characteristics of students' qualitative understanding that are relevant to their learning of mathematics and science. Instructional materials and methods rest on assumptions of the students' knowledge prior to the instruction, and if these assumptions are incorrect, instruction is likely to be ineffective, either being too difficult because students are lacking some prerequisite concepts or skills needed for the new learning, or not taking account of conceptions of students that could facilitate or interfere with their learning of new material.

Elementary mathematics. Recent findings require important revisions in assumptions about the conceptual sophistication of children when they enter school. Research by Piaget and others provided general insights into the reasons that many children might have difficulty mastering arithmetic in the early school years. For example, preschool children asked to say which of two sets has "more" objects often respond that there are more in a set that occupies a larger space, confusing spatial and numerical quantity. Although preschool children typically can count sets of objects quite skillfully, it has been assumed that this is an essentially mechanical skill, unaccompanied by appreciation of numerical principles such as cardinality and one-to-one correspondence. Recent research has been giving us a more precise picture of those aspects of numerical concepts that young children do and do not understand. For example, they are able to detect errors in counting performance that they observe, and they can adjust their counting procedures to accommodate novel constraints in ways that preserve principled constraints that make counting correct. Preschoolers clearly have significant components of understanding of fundamental abstract concepts before they begin their formal training in mathematics, a resource upon which instruction can build. On the other hand, other important aspects of number understanding such as the fact that a larger number can be viewed as composed of smaller numbers seem to develop later. This raises the possibility that instruction might be designed to be more effective in promoting such conceptual development.

Recent research also has shown that important conceptual prerequisites for some instruction are not reliably acquired in current instruction. An example is the teaching of subtraction involving multidigit numbers. Principles of the place-value system of enumeration should be understood by children in order for the procedures of column subtraction and borrowing to be understood adequately. A significant number of children do not acquire these principles adequately, with the consequence that numerous children develop incorrect, albeit systematic, procedures for calculation. Theoretical studies have shown ways in which understanding of place-value principles can be used in teaching arithmetic procedures so that they acquire integrated knowledge structures with correct skill and understanding of the constraints of correct calculation.

Preconceptions in physics. A predominant current view underlying curriculum design and teaching in science is that students' understanding of scientific concepts is shaped by their instruction. Much care is taken to avoid presenting incorrect or misleading versions of concepts in order to avoid the need for students to unlearn concepts and principles that are wrong.

Recent research has shown that this view is fundamentally incorrect. Students begin their study of science with strongly held conceptions about the phenomena that are explained by scientific principles, and their preconceptions are often inconsistent with the principles that they are to learn. Furthermore, their informal qualitative concepualizations often persist after a considerable amount of instruction in science, in which they have acquired formal knowledge based on principles that are inconsistent with their conceptualizations. They may use their formal knowledge correctly to solve textbook problems, but their understanding of events in the world is still based on the conceptualizations that they had prior to instruction.

Examples in physics have been investigated in some detail. Students' preconceptions regarding the motion of objects can be characterized as Aristotelian: for example, they assume that to keep a body in motion a force must continuously be applied to it. When asked about the speed of a falling object at different times after it is dropped, most students answer that it is falling at the same speed at all points in its descent, even though they solve problems correctly using formulas for linearly acclerated motion. Another example involves predictions that students make about the path of an object emerging from a curved tube. They believe that the object will continue to move along a curved path, rather than along the tangent to the curve, indicating an incomplete understanding of the law of inertia.

Implications for education. The view that students learn what they are taught is defintely too simple to be a useful guide for design of instructional materials and teaching. Students do not begin their study of mathematics, science, or technology free of prior concepts that influence their learning. In some cases they begin with significant prior understanding that exceeds the level assumed in current instruction; in other cases their preconceptions interfere with their understanding of the concepts and principles that they are taught.

We need to develop *instructional materials and methods that take account of students' existing conceptual understanding*, building upon it when it is sound, and bringing about changes in it when it is incompatible with scientific principles. A number of investigators are now studying methods of science instruction that take account of the student's existing conceptualizations.

A new perspective of the relation of basic skills and conceptual understanding is indicated by research on computational procedures. In most pedagogical thinking, skill and understanding are viewed as competitors for scarce instructional resources. Recent findings have revealed forms of understanding that are integral components of knowledge that underlies skilled performance, and that are essential to learning correct forms of computational procedures. For example, in learning the borrowing procedure in subtraction, it is important to understand that the total value represented by a numeral is not changed when one digit is decremented and ten is added to the digit to its right. These findings indicate that *skill and understanding should not be considered as competing alternatives, but not need to be provided in ways that reinforce each other in integrated cognitive outcomes of learning*.

Further research needs and opportunities. There is a need for research that analyzes learning as a process in which existing cognitive structures are modified by instruction. We need to conduct detailed analyses of effects on learning produced by students' existing implicit understanding of principles and their preconceptions about the subjects they are studying. There is a need for development of instructional materials in various science domains that take account of students' pre-existing conceptions.

We also need to investigate methods of instruction in which formal knowledge of technical formulas and computational procedures are integrated with relevant conceptual structures. There is a need for new systems of mathematical concepts and notation for representing and analyzing conceptual structures, and progress has been made in the development of such formal systems in recent research. Using formal systems for representing conceptual structures that are being developed, we are beginning to have the formal machinery to represent and analyze the kinds of mental models students and experts hold, what the underlying assumptions are, how the technical terms relate to other terms and most importantly, how a person uses these models to predict and/or rationalize a given phenomenon.

The study of mental models *per se* can be extremely subtle but with improved formal systems for representing conceptual structures we can begin to appreciate the crucial distinctions between seeing a student's view of the world that is faulty (from our perspective) versus really getting inside the student's conceptual framework and understanding what the technical terms mean to the student within the student's framework. Not only is this distinction crucial for being able to effectively remediate the student's faulty knowledge, but it also helps to predict why some faulty concepts are so resistant to remediation. In particular, what often seems incoherent from outside a given framework, makes perfect sense from within the framework, suggesting that local "debugging" of technical concepts might require a restructuring not only of a student's epistemology but also of the student's ontological commitments. For example, if the student views velocity as an intrinsic property as opposed to an (extrinsic) predicate, Newton's first law of inertia will be causally unexplainable. What does it mean to say that students have an Aristotelian view of physics based on their beliefs of inertia? What is their notion of state versus process? Can the Newtonian law of inertia be "accepted" without first viewing *both* rest and uniform motion as states? This shift from viewing uniform motion as a process to viewing it as a state is profound and the richness of this shift is not easily represented. But the formal systems for representing conceptual structures that are being developed can be used to examine these questions more rigorously and to formulate definite hypotheses about previously vague questions of understanding and representation. Indeed, *a major breakthrough in the teaching, acceptance, and use of science might stem from better understanding of how students can move from mental models that are sufficient for everyday reasoning, but are incoherent, to mental models that enable "thought experiments" whose coherence can be examined logically.*

II. FINDINGS OF RECENT RESEARCH

This section presents a brief review of findings obtained in recent cognitive and behavioral research of relevance to education in mathematics, science, and technology. To provide the Commission with a sense of the breadth of current work and the numerous investigators conducting the research, we describe each topic briefly, including names of some of the individuals whose research has contributed to that topic, and then mention very briefly a general finding or two that has resulted from the research thus far.

II.A. The Content of Education

The issues addressed in this section involved scientific literacy and general capabilities for problem solving and reasoning in mathematics, science, and technology and specific curriculum questions involving basic skills.

II.A.I. *Education for Effective Problem Solving and Reasoning*. First we discuss research relevant to the goal of providing education in mathematics, science, and technology that enables students to apply their knowledge effectively in problem solving, understanding, and reasoning in situations that they encounter in both academic and nonacademic settings.

Major scientific advances have occurred involving theories that characterize knowledge that is required for problem solving and for understanding. The theory of problem solving developed in artificial intelligence starting in the 1950's, and use of the ideas for psychological analysis was established by Allen Newell and Herbert Simon in their book, *Human Problem Solving*, published in 1972. General problem-solving strategies, such as means-ends analysis, were formulated and supported by observations of human performance in solution of problems. The theory of knowledge needed for understanding developed from analyses of language comprehension in artificial intelligence, linguistics, and psychology. Theoretical and empirical advances were contributed by Roger Schank and Robert Abelson of Yale University, Terry Winograd of Stanford University, Donald Norman and David Rumelhart of the University of California-San Diego, and Walter Kintsch at the University of Colorado. Cognitive structures corresponding to knowledge of concepts and their interrelationships have been characterized and hypotheses about processes of understanding have been supported in experiments on comprehension and memory of information in texts.

General theoretical concepts and methods for analyzing problem solving and understanding have been applied in the analysis of cognitive processes used in solving mathematical, scientific, and technical problems. Knowledge underlying students' problem solutions in high school geometry has been studied by Mary Grace Kantowski at the University of Florida, and by James Greeno at the University of Pittsburgh. An important result of these analyses is the characterization of the cognitive basis of students' problem-solving strategies, which have been largely implicit in instruction rather than being presented and taught so that students are aware of them. These strategies involve solution methods that are useful specifically in areas such as geometry that involve the kind of reasoning required in domains with axiomatic structure.

Analyses have also been provided of knowledge required for solution of word problems in arithmetic and algebra. Word problems in elementary arithmetic have been analyzed by Thomas Carpenter at the University of Wisconsin and by Mary Riley of the University of California-San Diego. A major result is the discovery of conceptual structures for understanding relationships between quantities described in problems that are needed for successful solution, and that are distinct from the arithmetic relations of addition and subtraction. These theoretical ideas have been considered by the authors of a series of mathematics texts, led by Joseph Payne of the University of Michigan, and are being used to improve the problem-solving materials in that text series.

Knowledge required for solving problems in physics has been studied by several investigators, including Jill Larkin and her colleagues at Carnegie-Mellon University, Frederick Reif at the University of California-Berkeley, Michelene Chi and her colleagues at the University of Pittsburgh, and Gordon

Novak at Stanford Research Institute. These studies, and others in which performance of experts has been analyzed in detail, have provided information about properties of the knowledge base used by experts in solving problems, including basic skills of perceptual encoding as well as recognition of the abstract theoretical principles that are applicable in a problem situation. Research has shown that selection of relevant features and relations and formation of organized cognitive representations prior to the use of solution procedures plays a critical role in successful problem-solving performance. Instruction in physics, as in other subjects such as algebra, emphasizes learning of formulas and procedures that are used in solving problems and neglects teaching the conditions that are required for the formulas and procedures to be appropriate. Research on problem solving has shown the importance not only of knowledge of procedures but also of the conditions for applying problem-solving procedures, and has shown how that information can be extracted from problem situations. Instructional methods based on these basic findings have been developed by Frederick Reif and Joan Heller at the University of California-Berkeley, and preliminary tests of those methods have had quite promising results.

There is now emerging a general theory of broad problem solving competence, including the following components: (a) mastery of basic knowledge and access to relevant facts and procedures in long-term memory; (b) useful problem-solving strategies, many of which now have been described in detail; (c) "control" or "executive" knowledge that good problem solvers use to make efficient use of their resources; and (d) general opinions that students have about the relevance of problem-solving techniques that frequently prevent them from attempting to use methods that they are capable of. Work on this characterization of broad problem solving skills has been contributed especially by Alan Schoenfeld at the University of Rochester.

Some investigators have begun to examine ways in which mathematical knowledge is used in nonacademic settings. These include a study of the use of arithmetic knowledge during shopping by Jean Lave at the University of California-Los Angeles, and a study of the use of mathematics for billing by drivers of milk delivery trucks by Sylvia Scribner at the City University of New York.

II.A.2. *Education for Technology*. Analyses of cognitive processes and knowledge structures required for problem solving and reasoning in technical domains can be carried out using methods similar to those in basic mathematics and science. Several investigators have studied knowledge and skill involved in electronics problem solving, notably, Gerald Sussman at the Massachusetts Institute of Technology, John Seely Brown at Xerox Corporation, and Mary Riley at the University of California-San Diego. These studies have shown the importance of knowledge for representing problems, consistent with results of research on problem solving in general physics. In addition, studies of learning and reasoning in electronics have provided information about interactions between qualitative causal understanding (how a system functions) and quantitative knowledge expressed in formulas (computational knowledge), and have shown that errors made by beginning students often are due to inadequate instruction in the qualitative properties of electronic systems. Analyses of methods for teaching the important qualitative properties have been undertaken, including work by the Dedre Gentner and Allan Collins at Bolt, Beranek and Newman, that emphasizes utilization of analogy between systems with the same qualitative structure.

Another practical domain in which important cognitive analyses have been developed is medical diagnosis, where investigations have been contributed by Harry Pople and Jack Meyers at the University of Pittsburgh, by Edward Shortliffe and William Clancy at Stanford University, and by Paul Johnson and his colleagues at the University of Minnesota, among others. These studies have provided information about the organization of knowledge and reasoning processes involving very large bodies of information. Some general properties in this domain are shared with the conclusions based on research in physics, mathematics and electronics, including hierarchically organized concepts in the memory of experts and problem-solving strategies. Distinctive conclusions have been reached about the characteristics of competent performance, including: the organization of knowledge used in diagnosis according to multiple principles, taxonomic knowledge of disease categories and causal knowledge of bodily function and disease processes, and coordination of these different kinds of knowledge as a critical feature of successful diagnostic reasoning.

Systems of computer assisted instruction are being designed for training individuals to work with technical systems. One system, designed by John Seely Brown of Xerox Corporation and his colleagues, is for training in electronic troubleshooting. This sytem enables a student to simulate the application of tests to obtain readings of relevant electrical properties of a device that is not functioning properly. The instructional system includes a sophisticated causal model of the device, enabling the student to understand the reasons for inferences that can be made from the readings. Another system called STEAMER is being designed by Albert Stevens and his colleagues at Bolt, Beranek and Newman Inc. STEAMER simulates the operation of a power plant, and will be used in training engineers. It also recognizes the importance of training students so that they can use causal principles about the system. The STEAMER system includes displays that show schematic representations of the power plant's internal structure, enabling students to observe effects of simulated changes in the system on properties such as internal pressure and rate of flow of substances that cannot be observed in real power plants. Thus, STEAMER illustrates the use of computer technology in training in which a simulation radically departs from the physical appearance of the real system, in order to provide crucial cognitive benefits that cannot be achieved in the real system or in a simulation that attempts to duplicate the superficial properties of the real system.

It is possible to study cognitive processes involved in use of technical systems either in terms of general cognitive principles or in terms highly specific to the technical system under investigation. Because of the rapid change in technology, highly specific work has a great danger of becoming obsolete before it can be used. Therefore, it is important to strive for general theory. The projects that we have described in this section illustrate investigations involving specific systems but with general cognitive principles being tested and developed as well. Studies at Xerox Corporation of text editing systems by Stuart Card, Tom Moran, and Allen Newell, and of instructions for operating copying machines by Lucy Suchman, also provide illustrations of investigations of specific technical systems that consider general principles.

II.A.3. *Training in "Basic" Cognitive Skills.* A long-standing issue in mathematics and science education has been the relative importance of teaching "basic" skills involving computational procedures and correct use of formulas vs. development of conceptual understanding. Traditionally much of the elementary curriculum has placed a major emphasis on skills. The curricular reforms of the 1960's challenged this emphasis and attempted to develop instructional programs that were more concerned with developing understanding of the structure of the subject matter disciplines. In reaction to this shift, the back-to-basics movement has redirected the focus back to skills. Today the importance of computational skills is again being challenged, especially in mathematics, where calculators and computers are available that can perform all the calculations taught in school.

Results of recent research provide a basis for resolving the perennial conflict between skill and understanding. Recent findings have provided new information about the nature of skill and conceptual understanding showing that these cognitive components are mutually dependent. Rather than treating them as conflicting goals competing for scarce instructional resources, we can begin to design curricular materials that lead to skills that integrally include conceptual structures that provide understanding and make the skills more useful in problem solving situations.

Research on elementary arithmetic has shown that a substantial number of children learn incorrect procedures for arithmetic calculation. This phenomenon has been analyzed in detail and related to general theoretical principles by John Seely Brown and his colleagues at Xerox Corporation. Their analysis indicates that some children generate and use procedures that ought to be ruled out by basic concepts that should constrain arithmetic computation, apparently because they do not understand these concepts or their application in arithmetic procedures. Their analysis of processes generates flawed procedures that indicate knowledge of basic concepts that children lack and that should constrain arithmetic computation. Other research by Lauren Resnick at the University of Pittsburgh has explored forms of conceptual teaching for the correction of children's flawed knowledge of arithmetic procedures. This has led to an analysis of an integrated cognitive structure of arithmetic knowledge that relates basic principles of numerical representation of quantity related to the steps of correct calculation.

There also has been research showing that the structure of relationships between basic number facts can be used to facilitate the learning of basic arithmetic knowledge. Rather than teach number facts as a set of mere associations between numbers as is the case in the flash card approach that is commonly used, instruction that explicitly builds on relationships among sets of facts provides students with a framework for organizing their knowledge and significantly facilitates learning.

Teaching that involves the structure of relationships among individual facts also has been studied in the domain of physics by Jill Larkin of Carnegie-Mellon University. She developed instruction that showed how formulas are related by conceptual knowledge, and trained students to use this knowledge in deciding which formula could be applied in the solution of a problem. This instruction facilitated problem solving, providing further evidence that integration of skill and conceptual understanding is both possible and beneficial.

Skill in computer programming is beginning to take its place along with skill in performing mathematical operations and in using scientific formulas as a basic goal of education. There have been several studies in which the cognitive processes of computer programming have been studied, including work by Peter Polson at the University of Colorado and by Elliot Soloway at Yale University. Important properties of knowledge required for success in computer programming have been identified, including a differentiated hierarchical structure of schemata that is similar to the organization of knowledge underlying other cognitive skills that have been studied.

An important question about computer programming as an instructional goal is the extent to which training in computer programming leads to general improvement in problem solving and intellectual skills. This question has been addressed in research by Karen Sheingold, Roy Pea, Midian Kurland, and Jan Hawkins of the Bank Street College of Education, and by Elliot Soloway at Yale University. In the study by Sheingold and her colleagues, there was no more transfer from training in computer programming to other cognitive activities than is the case for training in other subject-matter skills. In Soloway's study, transfer occurred from programming to solution of word problems in algebra. Further research is clearly required to identify the ways in which training in programming provides generalizable skill, and the conditions in which such skills are acquired. In any case, there may be some especially beneficial side effects of instruction in computer programming; the research by Sheingold and her colleagues showed that there was more student interaction and discussion of intellectual problems in classrooms where computer programming was being taught.

In addition to studies of cognitive skill in specific subject domains, research also has been conducted on general factors in learning success. One important area that is under study involves skills that people use in approaching problems and regulating and monitoring their performance. In the course of learning, effective students show regulatory performances that include such activities as planning ahead and efficiently apportioning their cognitive resources and their time, predicting the correctness or outcome of their performance, and correctly deciding when or what they know or do not know in a particular learning situation. These forms of decisionmaking are crucial aspects of efficient learning and problem solving because they enable an individual to use appropriate knowledge or to use appropriate procedures to obtain knowledge at the right time. Efficiency in performing them is particularly useful in facilitating transfer from learning and training situations to new situations. Research by developmental psychologists has indicated that these regulatory skills are predictors of success in the kind of problem-solving ability that produces learning, and that they are not well developed in individuals with difficulties in learning.

II.B. Participation and Effectiveness

II.B.1. *Enlarging the Successful Student Group*. An important condition for instructing a larger proportion of students successfully is to increase our understanding of the causes of their difficulty in learning. Major progress on this has occurred in recent research, especially in the identification of mistaken preconceptions that interfere with students' understanding of scientific concepts and principles.

There are profound educational implications of the findings that students begin their study of science and mathematics with implicit beliefs and tendencies to generalize their prior knowledge that are incompatible with the principles and procedures that they are supposed to learn. In current pedagogical thinking, there is considerable concern to avoid presenting incorrect information to students, but this is clearly not sufficient to prevent students from developing their own incorrect beliefs. Research findings have provided new understanding of why instruction can often provide students with ability to solve some problems correctly, but still leave them with an incomplete understanding of the subject. Frequently, the new vocabulary has been applied to their old concepts, and new formulas have been fitted into their previous knowledge structure. Remedial teaching generally consists of simply going over earlier materials again, as though students did not acquire the previous information completely; this ignores the fact that many students have formed procedures that are self-contained although incorrect. Thus, standard remedial teaching can be expected to be not only ineffective, but also to alienate students from the study of mathematics and science.

Research that has identified students' mistaken preconceptions has presented a common physical situation to students and used predictions that the students make as a basis for inferring the students' conceptions about the situation. An indirect method of assessment is required, since students frequently are unable to articulate their mental frameworks. Studies have been contributed by Michael McCloskey and his colleagues at the Johns Hopkins University, by John Lochhead and John Clement at the University of Massachusetts, and by Audrey Champagne and Leopold Klopfer at the University of Pittsburgh. The findings indicate that even college students tend to think of basic phenomena such as motion and force in a way akin to the physical theories developed by classical philosophers 2000 years ago. Examples of misconceptions have been identified that are counter to the principles of modern physics, such as that stationary, rigid objects do not exert forces; that a constant unbalanced force is required to keep an object moving with a constant velocity; and that air pressure causes gravity.

Research also has shown that students' prior knowledge affects their learning in mathematics. Studies by John Clement at the University of Massachusetts and Kathleen Hart at the University of California-Los Angeles illustrate these effects. For example, after being taught procedures for solving problems involving proportions, children tend to solve those problems using whole number operations that the children generalized from their earlier instruction, rather than using the procedures that they had been taught for computation with proportions.

Research investigations are being conducted to explore new teaching methods that take students' prior conceptions and knowledge into account. Examples of these investigations include studies by James Minstrell at Mercer Island High School in Washington, by Dedre Gentner at Bolt, Beranek and Newman Inc., by Susan Carey and by Andrea diSessa at the Massachusetts Institute of Technology, and by Audrey Champagne and Leopold Klopfer at the University of Pittsburgh. These investigators are studying methods such as componential breakdown of situations in which students make incorrect judgments, analysis of limiting cases that make students' errors obvious contrast of the learner's naive model with other more complete models, and discrimination training to make students cognizant of important distinctions that are neglected in their conceptualizations.

Along with findings that emphasize difficulties caused by students' prior knowledge and implicit beliefs, other findings have identified some important positive capabilities that have not been taken into account in the design of instruction. Many educators have concluded from Piaget's findings that children lack the conceptual structures needed to understand concepts of number, quantity, and causality until they are seven or eight years old, and that they lack important reasoning abilities such as the ability to reason hypothetically until they are in their mid-teens. Recent research by Rochel Gelman at the University of Pennsylvania, Thomas Trabasso at the University of Chicago, Ellen Markman at Stanford University, and others has shown that children have significant conceptual understanding of these concepts at much earlier ages than had been believed previously. Early understanding of these concepts is incomplete and largely implicit, but it is clearly not totally lacking, which means that instruction should be designed to capitalize on important conceptual building blocks that children have, rather than assuming that they have no cognitive basis for developing understanding of important abstract principles.

A major theme of the research that we have discussed in this section is the importance of understanding students' prior knowledge and conceptualizations to enable design of effective teaching of new skills and principles. In addition to new information about the kinds of prior knowledge and conceptualizations that students have, recent research has also provided improved methods for assessing the cognitive states that individual students are in prior to instruction. An example of these methods is in research by Robert Siegler of Carnegie-Mellon University, who has demonstrated that children's performance on specially designed sets of problems can be used to make sensitive diagnoses about the stages of understanding that they have reached regarding concepts such as the relationship of velocity, time, and distance traveled in linear motion. These studies also have identified stages of understanding that should be taken into account in designing instruction, showing that there can be intermediate states of partial understanding that should be achieved before there is an attempt to present a concept in its complete and complicated form.

The capability of educators to provide effective education in mathematics, science, and technology to an increased proportion of students will be enhanced also by increased understanding of processes of learning. Analyses of the cognitive processes involved in learning are in a relatively early stage, but some significant progress has been made. Contributions to this research problem have been made by John Anderson, by Robert Neches, and by David Neves at Carnegie-Mellon University, by Kurt VanLehn at Xerox Corporation, and by David Rumelhart and Donald Norman at the University of California-San Diego, among others. Important results of this work include analyses of how text information is transformed into cognitive procedures and how procedural knowledge in one domain transfers into new analogous procedures in another domain. Further results emphasize how difficult it is for learners to learn the conditions in which it is appropriate to apply the particular procedures or knowledge they have acquired. This reinforces conclusions from the study of problem solving that instruction could be made more effective if increased efforts were made to train students in the applicability conditions of procedures, rather than giving almost complete attention to the procedures themselves as often occurs in instruction at present.

Research on effective methods of teaching has also been conducted, including studies by Mary Budd Rowe at the University of Florida and by Allan Collins and Albert Stevens at Bolt, Beranek and Newman Inc. These studies have provided detailed analysis of the strategies that tutors use to formulate questions that probe and develop knowledge. Making explicit the strategies that Socratic tutors use should help more teachers achieve effectiveness in this style of learning, and generally provide insight into the interactions between students' existing knowledge and acquisition of new concepts and principles. In the more conventional classroom setting, instruction can be made markedly more effective if teachers provide more time for students to answer questions and pause briefly after questions are answered; the times involved are very brief, with increases of two seconds having substantial effects on a student's ability to process information before responding to questions. This shows that even quite simple features of classroom style and management can have substantial effects on learning experience. These results illustrate the interplay between general pedagogical issues and issues involving the specific teaching of mathematics, science, and technology. Just as these findings, obtained in research on teaching of science, contribute to general understanding of teaching practices, findings of research on teaching of other subjects provide important knowledge of use in the teaching of mathematics, science, and technology.

A major contribution to enlarging the group of success students in mathematics, science, and technology can be made by increasing the participation of women and members of minority groups in instruction in these fields. Recent research has provided information about factors that contribute to choices of courses in mathematics and science, and the effects that these choices have on entry into scientific, mathematical, and technical careers. Studies on these problems include contributions by Alma Lantz at ESR Associates, by Lauress Wise at American Institutes of Research, by Jacqueline Eccles Parsons at the University of Michigan, by Elizabeth Fennema at the University of Wisconsin, and by Wayne Welch at the University of Minnesota. Assembly of demographic information has shown that high school women's participation in mathematics courses has increased dramatically since 1960 and that women's participation in mathematics education generally is much better than is widely believed. Further, the research has shown that most of the sex difference in mathematics achievement is accounted for by differences in course participation.

Research on the determinants of course participation has confirmed some pre-existing ideas and disconfirmed others. Contrary to some usual beliefs, the extent to which a girl perceives mathematics to be sex-stereotyped and also her exposure to female role models seem to have little influence on enrollment decisions. Important determinants of participation in mathematics instruction include previous achievement in mathematics (not, however, an important factor in sex differences) and the individual's perception of the importance of mathematical knowledge. A girl's concept of women's roles in the world and of her own likely educational and occupational future does influence the usefulness that she sees in mathematics; this probably explains recent increases in enrollment. Prior achievement and ability level also are significant determinants of science enrollment. Interest in mathematics and a dimension characterized as "interest in things vs. interest in people" are important in differentiating science from non-science majors. As with mathematics, role models and perceived sex-stereotyping seem to be quite unimportant factors in determining participation in science education.

In the past decade, there has been considerable growth in the sophistication of evaluation methodologies. Now such complex questions can typically be addressed. In addition, some generalizations about intervention programs seem to be emerging. For example, lasting changes in attitudes and interests are not typically generated by passive media messages. These media materials, however, may be more effective when combined with face-to-face communication. Further, short "one shot" interventions do not appear to be highly effective while those spaced over a several-week period may be more promising.

II.B.2. *Educational Use of New Technology*. Research investigating cognitive and motivational factors in computer-based instructional systems has been contributed by several investigators. Contributions have been made by John Seely Brown and by Thomas Malone of Xerox Corporation, by Robert Davis and Sharon Dugdale at the University of Illinois, by Ira Goldstein of Hewlett-Packard Corporation, by Andrea diSessa at the Massachusetts Institute of Technology, by Allan Collins and by Albert Stevens at Bolt, Beranek and Newman Inc., by Audrey Champagne and Leopold Klopfer at the University of Pittsburgh, and others.

Among the concepts that have been investigated are use of computer-based systems for the development of more sophisticated problem-solving strategies by students, and the use of computational systems to simulate aspects of the environment that are unlikely to be observed in a real environment or that involve theoretically ideal conditions. One example is a system that shows graphically how a force applied to a moving object interacts with the existing motion of the object to produce a change in velocity. This requires students to revise a mistaken preconception that the final motion of an object can be completely controlled by the applied force, independent of its state of motion when the force is applied.

Research concerning motivational aspects of computer-based instruction has identified factors that contribute to the interest of instructional games. Important factors appear to include uncertainty of outcomes together with well-defined criteria for success in achieving goals. These are more significant motivational factors than are more superficial features such as use of music and similar superficial reinforcers when the student succeeds, at least in the preliminary studies that have been carried out.

II.B.3. *Testing and Instruction*. In recent years, there has been a series of major research programs that have provided assessments of the effectiveness and precision of testing for instruction and an analysis of theories on which the engineering of tests and test design have been based. Based upon former achievements in the psychology of individual differences and methods for the measurement of human behavior, testing has been developed to a substantial art and resulted in the development of major industries that supply testing instruments to education.

Also in recent years, the fundamental bases and properties of testing have been undergoing searching analysis and research examination. This has included examination of the ways in which tests are used in the educational process, and a reexamination of the theories of human behavior on which tests are based in the light of increasing knowledge of human cognition and the nature of skilled performance. At least two dimensions of this advance can be identified: (1) improved concepts and methods for diagnosis of individual differences in level of performance prior to instruction and for assessment of competence, knowledge, and skill that are acquired; and (2) the understanding and improvement of aptitudes for learning.

We have already discussed research advances that provide improved understanding of the nature of students' knowledge prior to instruction and the nature of cognitive skills that they acquire in instruction. As one application of this recent work, Herbert Ginsburg at the University of Rochester is drawing on contemporary research on children's mathematical thinking to develop a diagnostic test of calculation skill. The test focuses on strategies and processes underlying calculation: algorithms, systematic flaws, slips, and invented procedures. Properties of the test will be evaluated in relation to instructional purposes, particularly for remediation.

Regarding the nature of learning aptitudes, research has been contributed by Richard Snow and his colleagues at Stanford University, by Earl Hunt at the University of Washington, by Robert Sternberg at Yale University, and by Robert Glaser and his colleagues at the University of Pittsburgh, among others. Results of this research have contributed to development of models of the kind of performance that has been assessed on aptitude tests, e.g., language competence, the manipulation of abstract concepts and relationships, the ability to apply knowledge to the solution of problems and various perceptual and memorial capabilities. Recent models of cognitive performance have expressed detailed understanding of the nature of these abilities and the differences in performance of individuals with high and low measured levels of aptitude that can be considered in the development of new forms of diagnostic and achievement tests.

III. Research Needs and Opportunities

In this section we discuss questions for prospective research. We include topics for which research findings would have important implications for education in mathematics, science, and technology, and for which available scientific methods and concepts provide a strong basis for significant new investigations.

We begin with two general comments. First, the topics that are considered in Chapter II involve questions that merit further investigation to test the validity of our present conclusions and the applicability of the findings to additional topics in curriculum content and educational practice. Second, the conclusions that we have presented earlier require substantial efforts in applied research and development for their implications to be translated into concrete materials and methods for instruction.

In the remainder of this section, we identify important questions for prospective research involving new lines of inquiry that would be valuable, in our judgment, in addition to further development and application of the bodies of research that are discussed in Chapter II. We organize this discussion using the same general categories as were used in Chapter II.

III.A. Questions of Educational Content

III.A.1. *Education for Effective Problem Solving, Reasoning, and Cognitive Skills*. A central question regarding education's effect on students' general problem-solving and reasoning abilities is the question of transfer of knowledge and training. Scientific methods have been developed to the point that we can analyze the knowledge structures required for performance in problem tasks, and these methods can now be applied to enable individuals to use knowledge they have acquired in one domain to solve problems in another. Outstanding questions include the relative importance and instructability of general problem-solving methods and strategies, relative to methods and strategies that are tailored to the information and goals that arise in specific problem domains that occur in mathematics, science and technology. Results of research on this problem could provide valuable guidance for the development of educational programs in general problem-solving and thinking skills, which are receiving considerable attention, and which might be quite inefficient if they are being developed on the basis of implicit assumptions that turn out to be based on incomplete research findings.

A second research problem involves analysis of expert performance in mathematical, scientific, and technological domains. Much of this performance appears to involve processes that have become automatic for the individual. Research is needed to clarify the role of practice in the acquisition of these highly developed skills. A characteristic of highly automated skills is that they are relatively opaque and difficult to study scientifically. The nature of expert knowledge used in solving difficult problems (for the expert) is not well understood. Further, knowledge in the form that it is found in experts may not provide feasible instructional objectives for novices, who may need to observe performance in which the components and conditions are identified more explicitly than they are when an expert solves problems as examples for instruction. The relationship between knowledge as it occurs in experts and instructional methods needs to be examined thoroughly.

A third research problem related to these is a set of issues involving instruction in cognitive skills. Cognitive processes involved in the teaching of mathematics and science can be studied using the methods that now are used in studying problem solving and learning, and such studies would contribute needed information for the improvement of teaching and instruction. The design of text materials is based primarily on considerations of the organization of information in the subject matter. Organization of information for effective learning may differ from organization that provides the most elegant presentation of information in the subject matter. Studies of textbook content and structure in relation to the principles of cognitive skill acquisition that are being developed in current research would be valuable.

III.A.2. *Education for Technology*. Profound questions regarding our educational system are raised as our society gradually but inexorably becomes saturated with technology. Although craft technology preceded the rise of science and mathematics, the last half-century has finally seen technology become largely fueled by science. The result is the transformation of our environment to an artificial one—that is, an environment where relations are predominantly mediated by technology.

The main implication for education of the saturation of society with technology is that understanding technology becomes a primary concern, along with understanding science and mathematics. For it is not true that understanding science and mathematics conveys an equal understanding of technology. To understand science is to know the hidden structure of the natural world, to see it as a domain of laws and predictability. To understand mathematics is to know the power of formal abstract symbolism to describe the scientific view of nature, and to see how the prediction, control, and explanation of nature arises from these symbolic descriptions. These prepare one for technology, but they do not provide an understanding of it and its use.

Technology is what happens in the long run when purposive processes exploit nature. In the short run, there occurs simple application—the rational solving of problems. But in the long run there grows up a routinization of problem solving, in which the natural world gets permanently organized to permit purposes to be routinely attained. What results is a net of highly adapted artificial domains. The domains are law abiding and regular, but they are artificial in that they do not occur freely in nature. In Herbert Simon's felicitous phrase, the study of these domains can be called the *artificial sciences*.

Needless to say, very little is understood about what a student should learn about technology. We are only at the beginning edge of technological saturation. Our experience so far is that technologies are immensely diverse, each its own microworld of regularity. But in fact there are great underlying commonalities, although many of them can only be pointed to at this point. Students should understand that technologies tend to consist of components with laws of combination that are highly reliable and understandable. We make them that way so that design and operation are easy. Design is a universal activity with technologies, and design as a cognitive activity has much in common for all technologies. Indeed, knowing something of design permits understanding of many features of artifacts. Processes of control are important and full control almost always implies an explicit control system alongside the basic technology. Questions of error, maintenance, and repair are central, as are specifications, testing, and certification, also costs and economies, and finally side effects and latent functions. All these concepts have no place in natural science and rise to prominence only when nature is organized to meet pervasive goals.

The current view of technology is of unbridled diversity, as we humans exploit natural structure in all conceivable ways. However, the continued and spectacular growth of computers along all dimensions of performance and cost is leading to their use for the control of *all* technology. This will have fundamental consequences for the shape of technology as it is perceived and felt by the citizenry. Many aspects of our society will come to be mediated by common interfaces with common capabilities and characteristics. These interfaces will continue to evolve, of course, but in ever-new forms they will still provide a major constancy in our lives, like roads and buildings, and even language. Learning about technology will have as a major component learning to live and work with computer interfaces, networks, and software tools.

Education for technology must become a concern of our educational process, taking its place alongside education in mathematics and science. Students must be introduced to the fundamental concepts of technologies, to see these both in their general form and in diverse ways so they come to understand their generality and specific applications. Research is needed to provide clear characterizations of the cognitive skills and knowledge needed for successful performance and understanding in technological domains, similar to those that are becoming available in mathematics and physics. In particular, there is a need for study of how people understand technological systems, including characteristics of their mental models, both to aid in design of training for use and maintenance of the systems and in design of the systems themselves to make them comprehensible, usable, and maintainable.

In fundamental ways, education for technology does not differ in kind from education for science. The content is different, as indeed is the content of one science from another e.g., physics from chemistry or astronomy. But in other ways, the conditions are quite unique. First, we are at a very early stage in our understanding of technology as a general category. Thus the fundamental concepts are not as clear as are those of science. But even more, society is in a developing state with respect to technology itself, not just with respect to our understanding of it for intellectual and educational purposes. Thus the actual state of technology a decade hence will be quite different than its state now and new principles may well be emerging then.

The ascendancy of the computer as a universal control system provides a not too far-fetched example. With such a movement could arise the homogenization of technology, so that an immense amount of intercommunicability would be possible over *all* uses. Such constancies would have the utmost significance for the general use of technology by the entire population, and would rate a fundamental place in the characterization of technology. (Lest anyone still think this is too farfetched, consider the development of the physical bit (i.e., the two-state device) as the common coin for all digital technology. In the 40s and 50s machines were built with triadic logic and other non-binary logics. All that has disappeared, presumably permanently.) As technology in the school (and the rest of one's life) becomes ubiquitous, there will be no need to have a special computer laboratory with artificial problems in order to gain experience. The uses of the computer for many educational functions will provide "real-life" examples of technology in action. The correspondence of the means-ends structure of technologies to an individual's own means-ends structure of thinking and problem solving will require research to see whether persons' views of their own rationality constitute a "naive rationality" analogous to naive physics that is more an impediment than an aid in understanding the rational structure of technologies.

We need to know more about the cognitive skills and knowledge that are required for intellectual tasks in the nonacademic settings spawned by technological advances. Methods of cognitive analysis can be applied to identify knowledge structures that are needed for successful performance in technical occupations, and for successful use and understanding of technology in our lives.

The idea that technology joins mathematics and science as a triumvirate of basic domains seems to respond to important changes in our society. But some cautions are in order. One comes from the existing state of nonintegration of mathematics and science education. To a large extent, each goes its own way. If the result of adding technology is to create three separate educational domains, each following its own course, it might be better to forego the whole enterprise and simply muddle along. One possibility for hope is that the use of technology throughout the curriculum could perforce produce integration at a more rapid rate than the educational pigeon holes can promote its decay.

III.A.3. *Training in Cognitive Skills*. A major program of applied research and development is called for to design instructional methods and materials that exploit research results showing that conceptual understanding and formal skill are integrally related. In addition, the frequent occurrence of flawed procedures that are acquired by students raises the important research question of how incorrect procedural knowledge is learned. Investigation of this question will provide important information about fundamental processes of learning as well as indicating ways in which instruction can be improved to prevent the occurrence of incorrect learning.

Improvements in learning can come about by the design of a program of research and development that focuses on the learning skills that enable individuals to profit from instruction and further experience. The demonstrated importance of regulatory activities as a factor in learning success provides a basis for further investigation to analyze those skills in detail and determine whether they can be increased through instruction for general improvements in learning ability.

III.B. Participation and Effectiveness

III.B.1. *Enlarging the Successful Student Group*. We now understand that children have preconceptions about topics in science and mathematics that interfere with their understanding of concepts and principles. Research that investigates processes of changing students' mistaken preconceptions is in an early state, and can be conducted productively with available methods and concepts. We also know very little about the causes of children's conceptualizations. It seems reasonable to conjecture that many of them arise as inferences from ordinary experience—for example, to keep an object moving we must continually apply a force to overcome friction and gravity; perhaps this produces the pre-Newtonian inference that bodies in motion tend not to remain in motion. However, this reasonable conjecture should be examined and tested. A more subtle hypothesis is that the conceptualizations that children develop are a result of their effort to understand the phenomena that they experience, and have important explanatory functions in children's cognitive structures. If this is the case, the educational remedy for mistaken preconceptions will be much more complex than if the preconceptions are simply inductive generalizations. Rather than simply being faced with phenomena that contradict their preconceptions, children will have to acquire new explanatory concepts and relate them to the phenomena that they have understood previously in terms of a different set of concepts.

A closely related issue is whether understanding of modern concepts of science and mathematics requires proceeding through a series of stages involving incomplete and partially incorrect concepts, or whether an appropriately redesigned set of experiences would allow children to avoid the mistaken ideas that typically occur.

An important question for enlarging the group of individuals who understand scientific and technological principles involves the extent to which these principles can be acquired through informal experience that occurs outside of the academic setting. Scientific and technical information is available in our society in a great variety of settings, including museums and television. Systematic investigation of the processes of learning in these settings could provide important guidance for programs designed to disseminate information to the public in a broad way.

Cognitive learning theory is ripe for expansion into a theory that can speak to motivational issues such as those raised by computer games, by sex differences in math and science enrollment, and by public distaste for "school math" and "school science" concurrent with public interest as evidenced by the popularity of science magazines, television programs dealing with science, and home computers. Work is needed on the extent to which extremely high levels of motivation (e.g., from electronic games) help or hinder different qualitative types of learning, such as conceptual learning or practice.

Regarding participation of women and members of minority groups in mathematical, scientific, and technical education, simple factual information about some aspects of participation is still needed. In particular, information about the math and science participation of the members of various minority groups is needed. This information should be broken down by the relevant ethnic groups that can be expected to differ and by sex within them.

Research is needed to determine how much of the large effect of prior achievement is due to the intrinsic difficulty of continuing after poor mastery of prior work and how much is due to the selection, tracking, and counseling practices of schools.

Methodologically sophisticated measurement of the importance of factors other than achievement is needed, especially for populations other than the "general" population, and especially for factors such as interest, liking, confidence, and perceived utility that are to be the focus of intervention efforts. There is a need to determine the common and independent effects of these factors and prior achievement or ability.

There is a great need for research into the mathematical and scientific concepts and skills that are actually needed in a variety of life roles—whether as a common citizen, a business person, or as a scientific and technical professional. Students, teachers, and the general public have little knowledge of this and the perceived need for mathematical and especially scientific education is presumably reduced by that lack of knowledge.

Research into the early development of scientific interests is needed. Interest patterns seem to be a major determinant of participation in science, but little is known about their origin and development. Cognitive explanations of interest should be explored. It is possible that interest depends upon appropriate prior knowledge and experience. For example, females seem to have much less informal science-related experience with toys and hobbies in childhood. The possibility that the examples in science textbooks are biased toward majority male interests should be explored, as should effects of television programs such as "Cosmos" and "3–2–1 Contact," and other popular science media exposure upon science interest. Sophisticated evaluation of intervention programs designed to increase science participation is needed. To date there has not been a close correspondence between interventions designed to encourage participation and the research on significant factors involved in participation. For example, many of the interventions have focused on the presentation of role models, while the research has suggested the importance of achievement.

Despite the great increase in girls' enrollment in advanced high school mathematics, there are still great variations from school to school in the level of girls' participation. Research is needed to determine what characteristics of schools seem to promote high levels of math and science participation for girls, minority students, and all students, other than obvious factors such as high ability levels of the incoming students or the high socioeconomic status of the community.

Since there has been, and presumably will continue to be, some emphasis on interventions designed to encourage science participation, these interventions need to be based on existing research and to be thoroughly evaluated. These evaluations, while initially expensive, are the only way to ensure cost-efficient programs in the long run. Several methodological developments are needed; it is necessary to have adequate experimental designs and measuring instruments to assess the effects of an intervention. Further, assessment of short-term outcomes of global measures are not adequate. Long-term follow-up of specific components is needed. For example, many of the interventions combine many elements—academic enrichment, "hands-on" manipulation, and vocational information. It is imperative to determine the relative and/or combined effectiveness of these components. It is also necessary to determine whether there are differences in effectiveness for various individuals, subgroups, such as women and minorities, and whether these differences may be specific to certain ages, fields, or background characteristics of the learner.

III.B.2. *Educational Use of of New Technology*. Technology develops best when scientists with new theories are kept involved in the exploitation of their ideas. For this reason, an important form of research is the development of exemplary prototype instructional computer systems, both to lead the private sector and as research vehicles for more targeted basic research on learning and instruction. Some of the prototypes that seem most likely to be important are intelligent tutors that can help improve the effectiveness of the current teacher corps and, in fact, could provide instruction to both children and their teachers.

Prototypical systems also are needed to exploit the computer's capability to simulate and explicate mathematical and scientific principles. Systems of this general kind have been developed for topics in elementary mathematics and physics, but richer versions dealing in greater depth or with more complex subjects are now needed. More important, these systems need to be exploited as cognitive research vehicles. Protoypes are needed also to provide examples of use of environments for instruction in programming, and systems that provide diagnosis and assessment of students' specific knowledge and more general levels of capability in mathematical and scientific domains.

Experimental schools, in which the use of these tools in heavily saturated modes is possible, would substantially aid cognitive research on mathematics and science learning. Some systems should also be placed in nonschool settings (settings open to the public, such as libraries or museums) to facilitate research on updating the technological and scientific knowledge of the general adult populace.

A general issue that should be addressed in the context of the above systems is the extent to which intensive environments can be developed in which students are immersed in using science and mathematics. Do such environments result in substantially better learning? To what extent do integrated programs of mathematics, science, and technological content facilitate learning?

Computer-rich classrooms allow new styles of learning. Of particular importance are learning activities involving pairs or small groups of students, peer tutoring, collaboration/competition, etc. Observational and other research is needed in order to have a better description of processes and outcomes in such environments.

III.B.3. *Testing and Instruction.* Work is needed on cognitive psychometrics, a science of measuring the level of skill attainment in cognitive domains. With such assessment capability, work should proceed on the evaluation of novel programs of instruction, including use of programming environments. Particular attention should be paid to the extent to which skills learned in these domains transfer to other technological areas and conditions under which such transfer occurs.

Research is needed on aptitude differences and ways of tailoring intelligent instructional interactions to aptitude differences. Microtheory is well on its way that provides a basis for diagnosing deficiencies in cognitive procedures by specifying in detail the components of procedures that give errors in performance. There is a significant need for theoretical development for assessment of student's conceptual understanding related to their procedural knowledge, including their knowledge for representing problems and of principles related to general problem-solving methods. Theories dealing with more general aptitudes (e.g., reading facility, spatial/visualization skills) need much more work but have high potential long-term payoff. Some of this research should be specifically directed at differences that relate to equality of access by both sexes and by different races and cultures to math and science education.

IV. STRUCTURES FOR APPLICATION AND SUPPORT

In this final section we comment on some conditions that we consider important for the continued development and use of scientific knowledge about cognitive and behavioral processes relevant to education in mathematics, science, and technology.

We are particularly concerned with development of conditions that will increase the accessibility of research findings within the various communities that provide instructional materials and teaching services. The relationship between cognitive science and the educational community is not nearly as close as the relationship between physical science and engineering. To a large extent, the greater distance between science and practice in education results from the recency of development of many of the basic scientific ideas and methods. But current understanding of human cognition is at a point where it is important to develop conditions that enable the use of scientific results as easily and quickly as the usefulness of the results warrant.

A necessary condition for the development of new materials that take account of research findings in cognitive science is collaboration in research and development between cognitive researchers, specialists in the subject matter domains of mathematics, science, and technology, and educators. This is needed to ensure that instructional development will be informed by a deep understanding of the requirements of classroom instruction and of the conceptual structure of the disciplines to be taught, as well as the best available knowledge of learning and thinking processes. In the past, the programs of research and development in science education at the National Science Foundation have facilitated this kind of collaboration in valuable ways.

A critical dimension of efforts to facilitate application of research results is the training and retraining of teachers. One key difference between today's educational research climate and that of 20 years ago is a growing recognition that the teacher should be considered as a serious professional who can become involved in curriculum construction and the interpretation of research. Teachers should be collaborators in doing research as well. Programs should be considered that would enable teachers to spend substantial amounts of time regularly in collaborative research with other teachers and with cognitive and behavioral scientists. This would enable teachers to develop greater confidence and competence in developing curriculum for their own classrooms, and also to begin to understand and appreciate contributions that recent research in cognitive science can make to their teaching. Inclusion of teachers as collaborators in research would also benefit the research enterprise by providing continuing information about the context in which research findings will be applied.

Use of research findings also depends very strongly on the process of teacher training, and programs could be considered that would provide incentives for schools of education to develop innovative ways to include findings of recent research in their courses and in-service training institutes.

As with any science, research relevant to education in mathematics, science, and technology is a cumulative process that requires continuity of support if it is to maintain a productive level of contributions. The quality of American education in mathematics, science, and technology stands to benefit from maintenance of a stable source of support for scientific research on cognitive and behavioral processes. At the present time, there is scientific knowledge available that could be used for improvement of educational materials and methods, and an increased effort in basic research would provide further results of considerable value. We judge that an increased level of support would be beneficial for this work, and estimate that increased funding at a rate of as much as 20% per year could be used productively for major improvements in a citizenry prepared with the knowledge and skill required for personal growth and social contribution required in modern scientific, technological societies.

7 RESULTS OF A 50-STATE SURVEY OF INITIATIVES IN SCIENCE, MATHEMATICS AND COMPUTER EDUCATION

Report from the Education Commission of the States (ECS)
Prepared Under the Direction of Jane M. Armstrong, *ECS*

INTRODUCTION

This 50-state survey of mathematics, science and computer education initiatives was undertaken by the Education Commission of the States to identify the number and diversity of responses states have recently made to the national crisis in precollege mathematics and science education. Everyone is aware of the problems. They have been described in *Today's Problems, Tomorrow's Crises* (preliminary report of the National Science Board Commission on Precollege Education in Mathematics, Science and Technology), *A Nation at Risk: The Imperative for Educational Reform* (report of The National Commission on Excellence in Education), *Action for Excellence: A Comprehensive Plan to Improve Our Nation's Schools* (report of the Task Force on Education for Economic Growth), *Making the Grade* (report of the Twentieth Century Fund), to name a few recent reports, and now in the final report from the NSB Commission, *Educating Americans for the 21st Century.*

States have already begun to respond to the educational challenges. Several states have passed sweeping education reform acts in the past year; other states have earmarked millions of dollars to get computers into every school and train teachers to use them. More than half of the states have either recently raised their high school graduation requirements in mathematics and/or science or have increases pending approval. Nearly every state has taken some new initiatives to alleviate the shortage of science and mathematics teachers.

The descriptions of state initiatives that follow are the result of a questionnaire mailed to every state, followed by telephone interviews primarily with chiefs of instructional divisions, or governors' education aides and mathematics and science specialists in state education agencies. Written materials from states were used to provide additional detail. Recent state newsletters as well as articles in national publications were also used as sources of information.

The survey questionnaire asked states to describe their initiatives in grades K-12 in mathematics, science or computer education regarding: task forces or commissions; graduation requirements; instructional time; curricular guidelines or performance standards; special programs, schools, institutes or centers; and teacher training.

Only those state initiatives taken between 1982 and the present are included. Although hundreds of initiatives were privately or locally sponsored (for example, most curriculum is determined at the local level), these were not included either, since the emphasis of this survey was on state actions. Finally, initiatives which nearly every state is undertaking—such as assembling microcomputer laboratories at the state education agency for teacher training and courseware review—are not reported, since they appear to be so similar and widespread.

The Education Commission of the States is grateful for the support from the National Science Foundation to conduct this survey and other related activities.

I. TASK FORCES OR COMMISSIONS (Quality or Excellence)

The ***Alabama*** Interim Commission on Elementary and Secondary Science and Mathematics has recommended a reevaluation of science and mathematics education guidelines and requirements in elementary and early childhood education. The commission has suggested 30 minutes of science instruction daily in elementary schools and thorough review of the K-9 science curriculum. It is also recommending that an additional $1 million in state funds be made available to local education agencies for science laboratory equipment. Finally, the commission supports extending the contracts of science and mathematics teachers by one month to improve preparation for the school year.

Arizona Governor Babbitt recently appointed a 20-member statewide task force to study all aspects of Arizona education. The Committee for Quality Education is chaired by John Schaefer, former president of the University of Arizona. The Committee will examine the national reports on education and report back to the Governor on the status of Arizona education by October 31, 1983.

Under the Quality Education Act of 1983, a new state Education Standards Committee has been formed to recommend new curriculum standards for ***Arkansas*** public schools. The Act designates that the State Board of Education nominate 15 people, including teachers, school administrators, parents, college personnel and interested citizens. The law requires the committee to complete its study and file a report with the state board of education and with the Joint Interim Committee on Education of the Arkansas General Assembly by January 1, 1984. The committee will recommend proposed regulations, criteria and minimum standards to evaluate schools for compliance with minimum accrediting standards. New standards for the state's public schools must be adopted by March 1, 1984. The new standards would become effective June 1, 1987, allowing school districts three years to comply.

The State Department of Education in ***California*** has organized five task forces to develop model curriculum standards in (1) mathematics, (2) science, (3) computer education, (4) language arts and (5) history/social sciences.

Colorado Governor Lamm is appointing a state task force to study recent national education reports, the status of Colorado education and its relationship to state economic growth, teacher shortages in mathematics and science, and other issues. The task force will consist of state education officials, teachers, school administrators and members of the business and industry community.

The task force will present its recommendations to the 1984 Colorado legislature.

In July 1983, the Colorado State Board of Education established a curricular task force to study science and other subject areas within the state. The task force was created as part of the board's "Operation Renaissance," a project designed to upgrade education in response to the needs of a high technology society. The charges of the curricular task force are many, including increasing high school graduation requirements, basic student competencies, desirable teacher education program changes and the updating of teacher skills. The task force will make its initial recommendations in late September.

In 1982 the Colorado State Board of Education appointed a Task Force on Mathematics Education. The task force is composed of teachers, school board members, superintendents, principals and representatives from business and industry. The task force submitted its preliminary recommendations to the board in July 1983, which included: (1) three years of mathematics in grades 9-12 (the task force emphasizes mastery of skills, however, and realizes some students may reach mastery in two years), (2) three years of mathematics for the college bound and four years of mathematics for students entering mathematics- or science-related fields, (3) revision of certification and recertification standards for mathematics teachers and (4) more college preparation in mathematics for elementary teachers.

Delaware's Governor DuPont has recently established a new commission on excellence in schools, to be chaired by the Lt. Governor. The 32-member panel includes representatives of business and industry, parents' groups, universities and students as well as legislators, education leaders and heads of state agencies. The commission is charged with developing an "agenda for excellence," a plan for improving Delaware schools. To solicit citizen input, public hearings and visits to schools are planned. This group will submit its report, including recommendations and financing alternatives, to the governor prior to the 1984 legislative session.

The Delaware Committee to Insure the Availability of Professional Educators in critical Curricular Areas was recently created by a joint resolution of the legislature. This 21-member group, representing local education agencies, colleges, community groups and industries, will study teacher shortages in all areas including mathematics, science and computer education. In September 1983 the State Department of Education will conduct a major survey of school districts' mathematics, science and computer education programs. This survey will examine course offerings, teacher requirements and special needs and/or problems facing local education agencies, e.g., turnover and retirement. The results of this survey will be reviewed and utilized by the committee in the preparation of its reports to the legislature and Governor, which are due in January 1984.

The ***Florida*** legislature recently approved the organization of the Florida Quality Instruction Incentives Council which will be composed of 15 appointed members who will oversee the development of subject area tests and teacher performance evaluation instruments; suggest appropriate distribution of funds;

and oversee the implementation of educational reforms adopted by the 1983 legislature.

Recent legislation in Florida (38-B) requires the Commissioner of Education to develop a comprehensive state plan for the improvement of mathematics, science, and computer education programs in public schools. The plan will provide a framework for preparing and approving programs that address curricular goals, cost estimates for equipment and facilities, essential teacher characteristics and recommended courses of action.

In April 1983, the Florida Speaker's Task Force Report on Mathematics, Science and Computer Education was released. The recommendations will serve as a basis for developing new legislation to revitalize the curriculum in science, mathematics and computer education and to enhance the quality and quantity of teachers in these areas.

Governor Harris of ***Georgia*** has appointed the 40-member Education Review Commission, which was created by a joint House-Senate resolution. The commission is charged with defining quality basic education in Georgia and finding mechanisms for funding it. Ten commission members are legislators; other members are business people, educators and concerned citizens. The commission has already held two meetings. It hopes to prepare preliminary recommendations for the 1984 legislative session and will complete its work in December 1984. As part of its broad look at education in Georgia, the commission is expected to study issues related to mathematics, science and computer education.

The ***Idaho*** Board of Education created a Commission on Excellence. Their recommendations in September 1982 focused, in part, on increased mathematics and science requirements for graduation from high school. The state board is now preparing to implement the recommended standards, following evaluation.

The Governor's Task Force on the Quality of Mathematics and Science Education in ***Illinois*** is composed of staff from the State Board of Education, the State Board of Higher Education and the Governor's Commission on Science and Technology. The Task Force was established to study issues such as high school graduation and college entry requirements in mathematics and science, high schools for academically talented students, methods for improving teacher training in the use of computers, mathematics and science curriculum changes and improving teacher quality and skills through pre- and in-service training. The task force will complete its work in December 1983 and will report its recommendations in early 1984.

The Governor's Commission on Science and Technology is an ongoing commission of representatives from industry, the Illinois Board of Education and the Illinois Department of Education. The commission is studying precollege and postsecondary education related to science and technology, salary increases for professors, the development of high-technology industrial parks, research topics and other issues.

HR 326, adopted June 28, 1983, requires the Illinois Board of Higher Education to study the range of teacher training programs and the capacity of schools to train more mathematics and science teachers. The board will also examine the number of prospective mathematics and science teachers entering training programs and the number actually receiving certificates. The age and geographic distribution of new teachers will be documented. The board will inform the House of other academic areas where teacher shortages are developing. Recommendations are due no later than March 1984.

SJR 61 establishes the Commission on the Improvement of Elementary and Secondary Education which will study K-12 education in Illinois. The 20-member commission will report its recommendations to the General Assembly by October 1984. The commission will study all aspects of Illinois education, including mathematics, science and computer education. Members of the commission will be appointed by the Governor and will include five Senators, five Representatives, five members of the School Problems Committee and five people from the general public.

In March 1983, the Sunset Evaluation Committee completed a performance audit of the entire field of education in ***Indiana.*** The audit noted that the Department of Public Instruction needs greater policy direction if it is to improve the quality of education in the public schools. The audit contains 13 findings to assist the General Assembly in developing legislation needed for educational improvements.

In April 1982 Governor Orr appointed a 9-member commission to study and evaluate Indiana's primary and secondary education system. The Governor's Select Advisory Commission for Primary and Secondary Education was asked to identify—and make recommendations for the removal of—barriers which keep the system from attaining the highest quality education for Indiana students. Immediate recommendations from the commission are that the state develop loan and grant programs to reduce teacher shortages; establish and fund a computer training and loan program for teachers and students; expand gifted and talented programs; and appropriate sufficient funds in 1983 to address the identified needs.

The ***Iowa*** legislature has recently established an 11-member task force to develop a ten-year work plan for education in Iowa. A final report is due in November 1983.

The Department of Public Instruction and the Governor's office are co-sponsoring 15 public forums around the state to talk about the various recent national reports on education and their implications for Iowa. These regional meetings are to culminate in a statewide meeting in December 1984.

The Education Committee of the Iowa Academy of Science is an advisory group that makes recommendations on science to the Department of Public Instruction and the Iowa Academy of Science. The committee recently completed a report, at the request of the Governor's Science Advisory Council, on the status of science teaching in Iowa schools.

A major task force formed by Governor Ray reported recommendations on mathematics, science and foreign languages in November 1982. The legislature acted on many of these recommendations in 1983.

In February 1983, ***Kansas*** Governor Carlin appointed a Commission on High Technology whose primary task is to investigate ways to attract high technology industry to the state. Included in the commission's studies is how education can contribute to the state's goal of expanding its economy in high technology.

In June 1983, the Governor appointed a Governor's Cabinet for Education. The 13-member panel includes directors of the state's principal education organizations. Its major charge is to establish local citizens' advisory groups which will contribute to education policy making. The local task forces will study and make recommendations on the quality of public education in their school districts. Ultimately there will be about 300 local task forces. In addition to conducting the local task force advisory program, the Governor's Education Cabinet is studying education issues, including the quality of science and mathematics courses, merit pay, teacher preparation and student productivity. Recommendations to the Governor are due December 1983.

The Superintendent of Public Instruction in ***Kentucky*** appointed six task forces to study problems and make recommendations on the following topics: school finance, vocational education, accreditation, extended employment for teachers, and competency testing and assessment for teacher certification. The task forces are composed of citizens, teachers, administrators and state education agency representatives. Each group will report its findings in the fall of 1983.

The Science Advisory Council of the Kentucky State Department of Education recommended in April 1983 a "hands on" approach for teaching science to elementary students. The council also recommended identifying regional science resource teachers to provide immediate and knowledgeable support to science programs in individual schools and to assist inservice science programs.

In July 1983, Governor Brennan created the Governor's Commission on the Status of Education in ***Maine***. The charge to the 16-member commission is to review Maine's education system from preschool through college and to identify needed changes. Specific charges to the commission include identifying ways to improve the quality of learning in Maine's schools, assure quality teaching, improve vocational education, finance the educational system and increase public involvement in quality education. A preliminary report is due to the Governor by the end of 1983 and the final report, including recommendations for legislative action, is due December 1984.

A 21-member Maine Congressional Citizens Education Advisory Committee will complement the work of the Governor's Commission. The Committee will be looking at: (1) how Maine's teachers are hired and how much and on what basis they are paid; (2) how many students are in Maine's schools and what percentage go on to postsecondary education; (3) how the state pays for education; and (4) the federal role in Maine's educational system.

In June 1983, Governor Hughes of ***Maryland*** appointed the Commission to Study School Finance, which will probably consider differential pay for teachers in mathematics and science. The Maryland Board of Higher Education has appointed a Financial Aid Task Force that may recommend scholarships for teacher candidates in mathematics, science and other subjects in which teacher shortages are possible.

The Maryland Commission on Secondary Education, recently appointed by the State Board of Education, is undertaking a major three-year examination of the substance and structure of the state's public high schools. Individual task forces will examine graduation requirements, curriculum, student services and activities, instruction and instructional support, and school administration and climate. The commission will make recommendations to the state board. The analysis of graduation requirements and curriculum is to be completed by October 1984; recommendations are anticipated for changes in science, mathematics and computer education.

The statewide Commission on Quality Teaching presented its recommendations to the Maryland State Board of Education in October 1982. The board has not yet acted on the recommendations, but support seems strong for providing tuition assistance to train teachers in high-demand areas like mathematics and science.

Following a recommendation by his *Ad Hoc* Committee on High Technology, Governor Hughes will appoint an ongoing High Technology Roundtable made up of representatives from education and industry. The roundtable will address the needs of business and how education can help meet those needs. The particular focus of roundtable members will be engineering and technology in secondary and higher education.

In May 1983, the Maryland State Department of Education, the Maryland Academy of Sciences, the University of Maryland and the Governor's Science Advisory Council held a one-day workshop on "Potential Solutions for Maryland Science Education." Following the conference, the State Board of Education appointed representatives from industry, government and the schools to analyze curriculum and graduation requirements and to recommend, by October 1984, changes in science instruction in Maryland public high schools.

Quality and excellence for the future of ***Massachusetts'*** public education are top priorities within the state. In June 1983, Governor Dukakis appointed a commission to study elementary and secondary education, including adult basic literacy. Commission members include the Commissioner of Education and representatives from the Joint Education Committee, the Massachusetts Board of Regents and the State Department of Education. An advisory group composed of teachers, business and industry will assist the commission. The commission will study school finance, curriculum, merit pay, public-private partnerships and the relationship between technology and education. The commission's recommendations and a state education plan are due in December 1983.

The Massachusetts Department of Education sets up *ad hoc* task forces to study specific issues and disciplines. In 1983, three task forces are studying mathematics (finished spring), computer education (summer) and science (fall). The task forces' recommendations will be used to strengthen four state initiatives: (1) a statewide retraining program for science and mathematics teachers,

(2) a computer resource bank in science, mathematics and instructional technology, (3) a state clearinghouse on education and (4) a computer software advisory service.

The ***Michigan*** Superintendent of Instruction has appointed a Task Force on Mathematics and Science to study the current status of science and mathematics education in the state and develop recommendations for action related to state policy, funding and activities that will encourage support for the improvement of mathematics and science instruction. Subcommittees are studying certification, assessment, high school graduation requirements, use of community resources, state board policy related to science and mathematics and professional development for reassigned teachers. The final report is due in June, 1984.

The ***Minnesota*** State Board of Education appointed last fall a Task Force on the State-of-the-Art of Science Education in Minnesota. The 11-person task force is composed of university faculty, teachers and science supervisors. To date, the task force has distributed a survey throughout the state and results are being tabulated. The questionnaire surveyed teachers and principals in areas such as K-12 science curriculum, textbooks, instructional methods and use of audiovisual equipment. Results of the survey will be available in the fall of 1983, and there are plans to relate the results to science achievement data for the state.

The Minnesota Council on Quality Education (CQE) was established by the Minnesota legislature in 1971 to promote cost-effective innovations in public education. The council develops funding policies and procedures based on state law and recommends project grants for improving education, some of which involve mathematics, science and new technologies. The State Board of Education approves project grants and oversees the council. Projects funded under the program include efforts to develop new materials, design alternative education, equalize education opportunity and increase the use of new technology.

The Minnesota Alliance for Science is coordinating mathematics and science improvement efforts by business and industry, school districts, colleges of education and public agencies. The alliance was formed in early 1983 and is supported by the Bush Foundation and the University of Minnesota. Among its other duties, the alliance will develop a plan for recruiting, training and retaining more mathematics and science teachers. Recommendations will be submitted to the Minnesota Board of Education in the fall of 1983.

Minnesota Governor Perpich is planning to appoint a state commission on education for economic growth. The commission is expected to examine education issues related to the growth of technology within the state, including the skills required by students and teachers. Improving the business and industry contribution to public education is another issue the commission will study.

Mississippi's Performance Based School Assessment is a 17-member task force appointed by the Governor. The task force will propose a plan to establish guidelines and criteria for a performance-based school accreditation system in Mississippi. It is responsible for making recommendations concerning curricula and courses of study to the accreditation commission. The report is due by

April 30, 1984. The commission will be responsible for developing an interim, performance-based accreditation system based on the task force report. After July 1986, schools must comply with the standards and will be audited by trained evaluators.

A 15-member Commission on Teacher and Administrator Education, Certification and Development was appointed by Governor Winter for a 14-month term beginning July 1983. The certification commission is expected to set standards and criteria for public teacher education programs, establish standards for certification and recertification, and report on current practices and issues in teacher education.

Recent legislation in Mississippi requires the Department of Education to study the extent to which children master one level of coursework before advancing to the next; what may be done to assure that the progression is properly sequenced; and what steps are being taken to assure that children progress toward mastery of the material.

In March 1983, the ***Montana*** Task Force on Science reported its recommendations to the Office of Public Instruction. The charge of the task force was to assess the needs of science education, identify instructional goals and recommend actions for improving science education. Recommendations included upgrading certification standards for new teachers in grades K-12, improving the elementary school science curriculum, limiting laboratory class size and upgrading preservice science education.

The information from the Montana task forces for mathematics and science was used in an overall task force report, *Excellence in Montana Schools*. This report was completed by a committee of 26 individuals representing a variety of education and private sector interests and selected by the Superintendent of Public Instruction. The report was released in April 1983 and the Board of Public Education has adopted the report and is looking at ways to implement the recommendations.

In ***Nebraska*** the Governor's Task Force on Excellence in Education is using the two reports, *A Nation at Risk* and *Action for Excellence* to determine the status of education in Nebraska. The 30-member panel is composed of teachers, administrators, school board members, school superintendents, state senators, post secondary educators and citizens. The task force is using town hall meetings to collect information and make recommendations to the Governor by September. The Governor is expected to ask for rule changes and new legislation to implement the recommendations.

Senate concurrent Resolution No. 55, passed in the last ***Nevada*** legislative session, directs the legislature to appoint a special committee to study education in the state. The committee is required to study the report of the National Commission on Excellence and report its recommendations on Nevada's school system to the Governor, the Department of Education, school districts and the legislature. Recommendations are due by October 1984.

The ***New Hampshire*** State Board of Education established a State Commission on Excellence in Education to examine the report of the National Commission on Excellence and relate it to public schools in New Hampshire.

The commission is composed of 30 members representing teachers, the school board association, the school principals' association, the Governor, state college system, university system, private schools, the legislature and business. Six committees have been appointed to study higher education, economic impact, teacher certification, curriculum and graduation requirements, time on task and the process and effectiveness of schooling. The commission is expected to issue an interim report in October and final recommendations in January 1984.

In January 1983, the New Hampshire State Department of Education surveyed its 181 middle and secondary schools to collect statistics on science, mathematics and computer education classes. Questions covered enrollment patterns, course offerings and teachers' areas of certification. The state department is preparing a status report using the results of this survey.

The ***New Jersey*** Advisory Council on Mathematics and Science Teacher Supply and Demand issued an interim report in March 1983. The advisory council was established jointly by the Commissioner of Education and the Chancellor of Higher Education in the fall of 1982. The council consists of 15 members representing secondary education, postsecondary education and business and industry. Its charge is to explore the conditions affecting the teaching of mathematics and science (particularly in grades K-12) and to make short- and long-term recommendations for improving these conditions. The interim report suggests there is a need to increase the quantity and improve the quality of mathematics and science teachers in New Jersey. It also suggests improving the training, prestige and quality of work life for teachers. Priority recommendations include: developing career education programs that emphasize science and mathematics skills, endorsing the K-12 mathematics and science curriculum improvement objectives and encouraging school districts to share equipment and resources.

New Mexico Governor Anaya appointed a commission on higher education and a commission on elementary and secondary education to plan a major conference on education and high technology. The September conference will include legislators, school and university administrators and school board members. The conference is expected to generate recommendations regarding future links between education and high technology. The conference findings will be published and disseminated at a follow-up conference which will be held in October 1983, to solicit teachers' input. Joining in this exploration of the state's education future will be "Project Uplift," a future-oriented consortium of the state education agency, the Albuquerque school district and other local education agencies.

The ***New York*** State Board of Regents sets standards for the quality of education throughout the state with commissioner's advisory committees in each subject. The regents have begun a two year review of the goals and results of elementary and secondary education, involving citizens at regional meetings. The meetings are a continuation of highly successful regional meetings conducted for the past five years and have involved more than 20,000 participants who have provided the regents with useful public and professional reactions to major educational issues.

The Business Commission on Mathematics and Science Education in ***North Carolina*** is a statewide task force of businesses which assists in developing education programs, locating resources and obtaining commitment among businesses for education. A major activity of the commission is the identification of outstanding teachers who then receive awards and scholarships. Rewards are also given to outstanding businesses.

The North Carolina Governor's Task Force on Science and Technology is composed of scientists and engineers who are examining the impact of technological change within the state over the next 20 years. There is strong emphasis on education for economic growth, including issues concerning mathematics and science education in grades K-12. The task force is also studying research and training related to technological change. The task force's final report is due in November 1983.

North Carolina Governor Hunt is establishing a task force to examine the relationship between education and employment within the state. It will be patterned after the Education Commission of the States' Task Force on Education for Economic Growth. Governor Hunt will chair the task force and will appoint approximately 25 members representing the business, industrial and education sectors of North Carolina.

The North Carolina Mathematics Curriculum Study Committee will present the results of its two-year study to the State Board of Education in September 1983. The State Superintendent-appointed task force has made 62 recommendations to improve the quality of mathematics instruction for all students in North Carolina. Among the recommendations are integrating technology into the curriculum from kindergarten through high school, requiring each elementary student to have 60 minutes of mathematics daily and increasing high school graduation requirements in mathematics from two units to three. The recommendations also address issues such as teacher-pupil ratios, mathematics resource teachers and increased pay for mathematics teachers.

North Dakota Governor Olsen held a conference on Education, Training and Employment for the New and Emerging Technologies in June 1982. The purpose of the conference was to explore changing technology in North Dakota, the impact of that change on the state's workforce and the efforts of education and training programs to prepare students and others for the changing environment. Goals of the conference included increasing the quality of science, mathematics and computer instruction in elementary and secondary schools. Discussion groups at the conference focused on these issues and recommended what schools, business and industry, and the state government can do to help.

The Governor also convened a conference on public education in August 1982. A steering committee representing nine state agencies sponsored the conference. Discussions and questionnaire results centered on basic skills, goals of the American high school, secondary curriculum, changing social trends, teacher qualifications and test scores. Recommendations were made regarding what each state agency could do to improve the quality of education.

The Commission on Educational Excellence was established in October 1982 to assist in planning for the future of elementary and secondary education in ***Ohio.*** The tasks of the commission are to: identify and assess trends and issues that will affect Ohio schools, formulate objectives to be pursued by Ohio schools, and develop strategies for reaching these objectives. The seven major questions the commission has been asked to address are: (1) What will be the impact of technology on teaching and learning? (2) What type of delivery system will meet the educational needs of the future? (3) How can educators best equip themselves to function in a world of rapid change? (4) What should be the outcomes of learning? (5) How can educational quality be assured? (6) How can education professionals best be prepared? and (7) How can schools become more fiscally and programmatically accountable? To expedite the work of the commission, each question is being assessed in depth by one of seven task forces composed of commission members. The commission expects to complete its work and report to the State Board of Education in December 1983.

The Ohio Advisory Council for College Preparatory Education has recommended that college-bound Ohio high school students take three years of science and social studies, four years of English, three years of mathematics and two years of foreign language. The council was jointly created by the Ohio State Board of Education and the Ohio Board of Regents to study issues of college preparatory education.

The Ohio Department of Education has recently released a report, *Moving Toward Excellence,* that documents Ohio's educational progress in light of the National Commission on Excellence's report, *A Nation at Risk. Moving Toward Excellence* highlights new educational standards, increasing learner productivity, strengthening teacher education, identifying instructional uses of computers, implementing school improvement programs and strengthening vocational education.

In June 1983, ***Oklahoma*** Governor Nigh created a 25-member study commission to review the feasibility of establishing a state residential school for mathematics and science. Such a school would be particularly beneficial to rural students who frequently do not have access to a full range of courses in secondary mathematics and science. The commission is expected to submit a report and budget to the Governor in October 1984.

The Committee on Science and Mathematics Education in ***Oregon*** was formed to assist the Superintendent of Public Instruction. The committee is studying the quality of mathematics and science education, student needs, plans to strengthen instruction and cooperative programs with businesses. The committee will submit specific recommendations to the superintendent by December 1983.

The ***Pennsylvania*** State Department of Education has established a Science and Mathematics Task Force. The Task Force is examining statewide needs over the next five years in science, mathematics and computer education and their implications for curricula, equipment, teacher supply and demand, and teacher training. The task force recommendations are due November 1983.

The ***South Carolina*** Department of Education completed two task force studies in January 1983 which provided the basis of the new "Move to Quality" program, a 41-point plan by the state superintendent. The plan will "accelerate progress and improvements" by increasing academic standards and vocational education standards, as well as target funds into mathematics and science education expansion. It is expected that the plan will receive top legislative priority in 1984. The Department of Education has taken the task force results into consideration and approved new curriculum guidelines and increased graduation requirements.

In June 1983, Governor Riley of South Carolina appointed a blue ribbon panel to look at the long-range question of excellence in South Carolina public education, with particular emphasis on science and mathematics. A priority of the panel is to improve education for South Carolina's growing high technology economy.

Also in June 1983, the Governor appointed a 25-member business-education partnership panel to work with the educational excellence panel. The panels will recommend ways business and industry can contribute to public education policy and will study mathematics and science education.

The ***South Dakota*** Joint Boards Task Force is composed of members of the Board of Regents and the State Board of Education. The task force is holding hearings and forming recommendations on high school and college graduation requirements, curriculum content and education policy as a whole. The task force will continue its review into the 1983-84 school year.

South Dakota Governor Janklow is appointing a State Commission on Excellence to study the recent national education reports and their implications for the state.

The ***Texas*** Education Agency, in response to the 1981 legislation, is seeking improvements in curriculum and changes in graduation requirements. With the assistance of various professional organizations, parents, teachers and administrators, staff at the state agency developed recommendations which include the following: (1) the adoption of essential elements that students in public schools must master in various courses, K-12, (2) an increase in the total credits needed to graduate from high school, (3) an increase in the mathematics graduation requirement, from two to three years, and (4) an increase in the science graduation requirement, from one to two years. Although computer literacy was not among the required subject areas identified by the legislature, the state education agency developed a set of essential elements for review and consideration. Citizen reaction will be considered in developing the final recommendations and implementation policies, which will be presented to the State Board of Education in October.

The Texas Select Committee on Alternative Schools and the Committee on Technology, two bipartisan legislative committees formed to improve general education, have operated over the last two years and have focused much of their attention on mathematics and science instruction. Some of their recommendations were proposed to the legislature but not passed in the recent session.

The Texas Select Committee on Public Education, an 18-member panel appointed by the Governor, is following up on the alternative schools and technology committees' work. The Select Committee is composed primarily of citizens and legislators and will advise the Governor on issues related to mathematics and science teaching, education quality and education finance. It is anticipated that the committee on public education will present its recommendations to the Governor sometime in late fall.

Governor Matheson of ***Utah*** appointed a 20-member panel of legislators, business leaders and state education officials to advise him regarding political and financial issues facing public education. The Steering Committee on Education Reform will be reviewing and discussing the implications of two national reports, *A Nation at Risk* and *Action for Excellence*, as well as current state initiatives. It is anticipated that the group will focus on three major issues: the teaching profession, technology in the classroom and the funding of state education initiatives. Members of the steering committee have commissioned a poll of Utah citizens to ascertain their major education concerns, how they feel these should be addressed and what kinds of funding alternatives would be acceptable. The committee will consider the results of this poll in designing a legislative package for the 1984 session. The public will be asked to comment on proposed programs. A final report reflecting the committee's recommendations and public reaction to proposed programs will be sent to the Governor by January 1, 1984.

A legislative interim committee in Utah is currently reviewing proposals dealing with the teaching profession and will be developing a legislative package for the next session. Attention is being given to such issues as financial incentives for teachers serving in high-need areas, career ladders and improved evaluation systems.

The Utah Board of Regents and the State Board of Education have jointly organized and appointed the Committee for the Improvement of Teacher Education. Citizens and educators are now studying professional preparation programs, including programs in mathematics and science, and will submit a set of recommendations before January 1, 1984.

The Governor's Commission on ***Virginia's*** Future has just organized an education task force as one of five task forces studying issues related to the future and well-being of the state. The education task force will study student achievement and performance, instructional quality, organization, governance and funding. The report is due to the Governor by December, 1984.

The Lt. Governor of ***Vermont*** is chairing the Vermont Seminar on Education. The panel is composed of leaders from business, industry, education and government and is studying high school graduation requirements, curriculum and instructional improvements, and teacher preparation, certification and recruitment. The seminar will issue its report during October 1983.

In August 1983, the Superintendent for Public Instruction in ***Washington*** will appoint an interdisciplinary statewide advisory task force to oversee the development of competencies in education. Mathematics will be the first subject addressed; science and computer literacy are tentatively scheduled for competency development in 1984-85.

In May 1982, Washington Governor Spellman established an Advisory Committee on High Technology Training and Advancement. Representatives of business, organized labor and selected state agencies, as well as educators and legislators, were appointed by the Governor to: (1) examine and evaluate how the state now provides high technology education, training and technical assistance as well as the demand for those services by Washington state employers; (2) identify programs to encourage high technology growth; (3) identify training and technical resource barriers to high technology development and (4) develop and submit to the Governor, before the 1983 legislative session, a report containing recommendations for legislation, innovative programs and other actions that will promote high technology training and advancement. The committee's initial recommendations to the Governor were the basis for additions to the Governor's budget request for the 1983-85 biennium and for enactment of legislation to support a package of high-technology education and training programs.

In Washington, the Governor will soon appoint citizens to the Coordinating Board on Technology Education, a group which will oversee implementation of the entire High Technology Education and Training Act. This act provides funding for K-12 and postsecondary programs in technology education and training.

The Washington Committee on Education Policies, formed in 1982, is charged with conducting a review of public education systems and governance structures within the state. The promotion of quality and excellence in education at all levels, while maintaining access and equity, will be the focus of this group's efforts.

The ***West Virginia*** State Board of Education developed the "Master Plan for Public Education in West Virginia" earlier this year. Prepared with the assistance of a 99-member advisory committee, the plan is a blueprint for long-range educational change in the state.

A West Virginia statewide advisory committee, composed of superintendents, teachers, higher education personnel and others, will be appointed shortly by the State Superintendent. The committee will make recommendations to the State Board of Education concerning adoption of learning outcomes for a number of areas including mathematics and science. Prior to the advisory committee's review, an extensive verification process will take place and will involve educators and administrators from every county in the state. It is anticipated that the learning objectives will be adopted by the State Board of Education before January 1984.

An interim committee of West Virginia legislators is studying science and mathematics improvement along with other issues of the "Master Plan for Public Education." The committee will make recommendations for enhancing mathematics and science programs, including forgivable loans and scholarships for prospective teachers, alternative training systems and a state mathematics-science high school.

In June 1983, the Superintendent of Instruction announced the appointment of a 29-member Blue Ribbon Committee on Quality Education in ***Wyoming***. The charge to the committee is to address two questions: (1) Can the citizens of Wyoming expect both quality and quantity from their schools? and (2) If so, at what cost? The committee is expected to define quality education, decide what to expect of the schools and determine the costs—in dollars and in attitudes, traditions, policies and statutes. A report is due to the State Board of Education by October 1984.

In February 1983, a Task Force on Curriculum and Staff Development was formed in Wyoming to make recommendations on developing and evaluating all K-12 curricula. The task force will also suggest proposals for staff development programs. Recommendations are due in the fall of 1983.

II. TASK FORCES OR COMMISSIONS (Computer Education)

The ***Alabama*** Department of Education's newest task force is the Computer Literacy Commission, established in the spring of 1983. Its mandate is to review all curricula in grades K–12 to identify where computer education can and should fit into Alabama's public schools.

In response to the request of the twelfth ***Alaska*** legislature, two separate task forces examined different areas of computer education and reported their findings to the Alaska Department of Education and local districts for program planning and implementation. Both groups were composed of representatives from a diversity of regions and interests from state and local education agencies, colleges and universities and the private sector involved in computer applications. The task force on computer literacy provided guidelines for developing a state plan for a computer-literate population of students and adults. *The Statewide Computer Literacy Study*, published in January 1983, reports on the task force findings and is available from the Alaska Department of Education.

The Alaska Task Force on Computer Networking in Education studied the feasibility and cost effectiveness of local and statewide networking systems, such as electronic mail and video transmission. The task force, in its January 1983 report, recommended additional development of computer networking by the Alaska Department of Education.

The ***Arkansas*** State Department of Education and the Southwest Educational Development Laboratory cosponsored a conference in December 1982 to identify computer literacy competencies needed by students and teachers in the public schools. Approximately 30 representatives from school districts, colleges, community colleges and the State Department of Education participated, making recommendations about competencies and suggesting ways school districts or professionals could work together on implementation. The task force report is serving as a basis for discussion in the local districts and for possible new legislation.

In November 1982, the ***Colorado*** Department of Education set up a statewide computer advisory committee to recommend department services that would be most beneficial to Colorado schools. The most important department goal, says the committee, should be assisting schools in developing computer literacy and using technology curricula. Other important goals include department-sponsored conferences for school personnel in technology applications and technical assistance to public schools.

The ***Connecticut*** State Board of Education and the Board of Governors for Higher Education formed a joint committee in May 1983 to examine the use of computers, libraries, media and instructional materials to enhance education. Their report will be released in September 1983. There is also a move to organize a computer teachers' association.

The State Department of Education in ***Georgia*** is organizing an in-house task force, with representatives from all departments, which will be charged with developing a state plan for the use of technology to support instruction and the management of instruction. The task force will also seek to identify sources of funding for equipment, software and staff development and ways to involve business and industry. Realistic plans for staff development are another priority.

The ***Hawaii*** Office of Public Instruction Services sponsors a computer education committee and a Task Force on Computer Literacy. These task forces are studying ways to integrate the computer into the curriculum and suggesting curriculum content for computer education courses.

HR 327, adopted June 28, 1983, directs the ***Illinois*** State Board of Education to establish a computer literacy advisory committee to study the use of computers and other electronic equipment in teacher training programs. The state board will report study results and recommendations by March 1984.

For two years the ***Kentucky*** Department of Education and the Kentucky Educational Television have worked together conducting a survey of the status of microcomputers in local districts. The second survey was completed during 1982 and indicated that the number of microcomputers in local districts had quadrupled from 450 to around 1,800 since the first survey was completed in the fall of 1981.

Last year, ***Louisiana*** established a Superintendent's Task Force on Computer Education which examined the implications of requiring computer literacy for high school graduation. The *ad hoc* task force consisted of teachers, students, parents, college faculty, administrators and members of the Department of Education. The task force recommended that computer education be integrated into all K–12 curriculum, not taught as a separate course. The task force submitted its recommendations to the state board but no action has been taken yet.

The Superintendent in ***Maryland*** has appointed a group to look at the use of technology in the classroom, grades K–12, using a preliminary staff report on computer instruction and computer literacy as a starting point and making recommendations to the Board of Education.

The ***Minnesota*** Education Technology Act, passed in May 1983, required the Governor to appoint a 15–member advisory committee on technology in education by July 1, 1983. Committee members include public school teachers and administrators, parents and representatives from school boards, the Department of Education, the Minnesota Educational Computing Consortium, higher education and business and industry. The committee will assist with planning for technology use in local districts, inservice training, technology demonstration sites and courseware package development and evaluation. The advisory committee will terminate June 30, 1985.

The ***Missouri*** Department of Elementary and Secondary Education has set up an in-house task force to study the use of computers in instruction.

In early 1982, the Office of Public Instruction formed the ***Montana*** Task Force on Computer Education. Members of the task force included teachers, university professors, school administrators and state curriculum specialists. The task force produced a handbook, *The Elements of Computer Education: A Complete Program*. This publication provides evaluations of hardware and software, curriculum ideas, program planning, administrative applications, staff development plans and a resource directory. The task force is considering developing videotapes for classroom instruction.

In Montana, a SLATE conference was held in June 1983 to determine priorities for using educational technology. Seventy-six participants attended including teachers, college faculty, state education department and state board members, the regents of the university system and industry leaders. The group recommended that a Montana Commission on Technology in Education be created by the Governor to develop a state plan for using technology in education, including the training of all Montana citizens in the use of computers. They further recommended that a statewide communications network be established to exchange technology information throughout state government and education institutions.

Nebraska's Committee on the Utilization of Technology in Education was recruited by the Commissioner of Education in 1980 to identify persons in education organizations in Nebraska with an interest and involvement in computer technologies in education. The Committee is an ongoing forum for information sharing in all aspects of computer use including: identifying software, maintaining a list of professionals involved in computers and technology in education, examining the use of a videodisc curriculum and creating a statewide telecommunications network. One subcommittee is examining teacher inservice education in computer use.

The ***New Mexico*** Governor's Commission on Public Schools is specifically charged to bring its findings and the findings of the September/October high technology conferences to the Governor prior to the 1984 New Mexico state legislative session. It is expected that the 1984 session will be an "education session."

To document the growth of technology-based education in ***Ohio***, a survey of all school districts is being conducted to determine the kinds of computer hardware being used, the grades in which technology is being used for instruction, the subject areas in which technology is used and how technology contributes to the inservice education of teachers. Other types of information being collected by the survey include the ratio of students to available hardware and software, the types of computer applications being used and the use of personal computers. The results of this survey will be used as a data base from which to form questions about the role and value of technology-based instruction.

In ***Oklahoma***, the Governor's Council on Science and Technology oversees the Higher Education Technology Task Force and the Educational Planning and Assessment Committee of the State Department of Education. This "consortium" task force considers the future standards and quality of computer education as well as science and mathematics, at all levels of education, throughout Oklahoma. It also monitors competitive grants to local education agencies for microcomputer purchases for the state's gifted and talented programs.

The ***South Dakota*** Department of Education and Cultural Affairs and several South Dakota colleges and universities are forming a task force on technology to examine requirements for computer literacy, computer access and related issues of technology and education.

The ***Tennessee*** Statewide Microcomputer Advisory Committee was established in 1982 to study the status of computer education in the state and make recommendations for its improvement. To date, the committee has developed a curriculum and three-year plan for computer literacy in grades 7 and 8 (Computer Skills Next). Components of the plan include: (1) goals and objectives for computer literacy curriculum, (2) teacher training in computer literacy for grades 7 and 8, (3) the acquisition of microcomputer hardware and (4) additional resources needed at the state level. The committee is presently focusing on guidelines for computer science in high school.

A statewide computer literacy committee made up of ***Utah*** citizens and educators is now reviewing proposals for the development of computer literacy courses in schools, K–12. This group was organized by the Board of Regents and the State Board of Education.

The State Department of Education helped create the ***Vermont*** Educational Computer Technology Organization (VECTOR) which implements comprehensive computer information for local education agencies. In cooperation with the Vermont Department of Education, VECTOR established a statewide computer network in the summer of 1983. The department has published *Computer Considerations for Vermont Schools* and offers inservice workshops on computer awareness, literacy and competence. It also conducts an annual survey of the use of computers in Vermont schools.

The Governor's Science and Technology Task Force in ***Virginia*** is examining issues related to the state's economic growth and how an education system with excellent mathematics and science programs can attract future-oriented industries. The task force is composed of educators and representatives of business and industry. Recommendations are due August 1983.

The Virginia Microcomputer Inservice Training Task Force is composed of 20 local teachers, school administrators and representatives from Virginia colleges and universities. The task force is studying computer curricula for teachers and has recommended a three-tiered curriculum representing an increasing mastery of skills.

The ***Washington*** Office of the Superintendent for Public Instruction has had a Computer Technology in Curriculum and Instruction Task Force in operation for the last two years. This interdisciplinary group was organized in response to the identification, by citizens and educators, of computer technology as a high priority in education. The task force assists local education agencies in using the computer in the classroom. To that end, a handbook on computer technology was developed and disseminated to districts. This manual includes information on purchasing equipment, evaluating software, staff development, available resources (organizations, publications, etc.) and a directory of local education agencies in the state that currently use computers.

At its May meeting, the Washington State Board of Education approved the formation of a task force to review school district needs in computer education and to make recommendations concerning technical assistance to meet identified needs. Technical assistance will then be provided through the office of the superintendent's new Computer/Technology Education unit recently established and funded through the High Technology Education and Training Act.

The ***West Virginia*** Task Force on Technology in Education is a 34–member panel of educators, parents and community leaders appointed in June by the state commissioner. It is to consider the use of computers and related technology in the classroom and recommend programs and fiscal alternatives to meet the goals of the state's master plan for computer literacy. (Within three years high school are to have computer literacy programs; within six years middle schools are to have such programs.)

State Superintendent Grover appointed a task force to undertake a thorough review of teaching in ***Wisconsin***. One directive to this Task Force on Teaching and Teacher Education is to determine the implications of technology for the preparation and professional development of teachers. The task force members include citizens, teachers, business and industry representatives, and educators. The final report and recommendations are due December 20, 1983. A preliminary report will be available in October.

A recent report, *Instructional Computing in Wyoming: Status and Recommendations* describes the nature and extent of computer use in grades K–12 in the ***Wyoming*** public schools. It summarizes teachers' opinions about the potential uses of computers in the school and reports the recommendations that a select committee of Wyoming educators made about statewide development of instructional applications of computers.

III. GRADUATION REQUIREMENTS

NOTE: States that do not mandate high school graduation requirements are not included.

Alabama has recently increased its graduation requirements to 20 total units, including one new unit in science and a second in mathematics. Beginning with the 1985 graduating class, all students in Alabama will be required to pass an exam in reading, language and mathematics to graduate.

Current high school graduation requirements in ***Alaska*** include one credit of science, one credit of mathematics and 19 total credits for graduation. The state board of education is considering increasing mathematics and science requirements for all students and will report on changes this fall. The high school curriculum will be revised by December 1983.

Beginning with the graduating class of 1987, all high school seniors in ***Arizona*** will be required to complete two years of mathematics and two years of science. No requirements for computer education are mandated at this time, although students may take one-half year in "Computer Awareness" to satisfy one-half year of the mathematics requirement. Twenty total units will be required for graduation. In addition, the Board of Regents will require, beginning in 1987, three years of mathematics and two years of laboratory science for admission to the three Arizona state universities. Students may meet the requirements in several ways, including the attainment of specified minimum scores on standardized tests.

In 1982–83, ***California*** set no requirements for graduation (requirements have been the responsibility of school districts since 1968), other than to specify that students must take some mathematics and science. In July 1983, Governor Deukmejian signed SB 813, an omnibus school-reform bill that requires all students to complete two years of mathematics and two of science (this requirement will be met by students who graduate in 1987).

There are presently no specific gradation requirements for science, mathematics or computer education in ***Connecticut.*** However, new legislation will require 18 units for high school graduation in the class of 1987. The state department of education has curriculum recommendations in science, mathematics and computer education.

Students starting high school in ***Delaware*** in the 1983–84 school year will be required to have 19 total units to graduate, with two units mandated in mathematics and two in science.

Effective the 1984–85 school year in ***Florida,*** three credits each of mathematics and science will be required as part of the total 22 units needed for graduation. Beginning with the 1986–87 school year, the total number of units will be increased to 24.

Georgia is considering requiring 21 units for graduation, including two units of science and two of mathematics. (Earlier requirements: 20 units in all, one in science, one in mathematics and a third in either science or mathematics.) Students must pass a basic skills test to graduate.

The 1983 graduating class was ***Hawaii's*** first graduating class required to complete a total of 20 credits, including two credits in science and two credits in mathematics. These graduation requirements were first set in place in 1978–79.

Idaho requires one year of mathematics and two years of science for high school graduation. Students entering high school in 1984 will be required to take an additional year of mathematics. At that time, they can substitute one unit of computer education for one mathematics unit. For these 1988 graduates, 20 units will be required for graduation.

Minimum requirements for graduation are currently identified in rules and regulations filed by the ***Illinois*** State Board of Education. The requirements state that a student must complete at least 16 units in grades 9–12 in a four–year school or 12 units in grades 10–12. Science and mathematics requirements are currently determined by local school boards. However, two bills have just been sent to the Governor that will require the successful completion of science and mathematics (and other) courses for graduation. SB 669 requires two years each of mathematics and science and would apply to 1984–85 incoming freshmen. HB 1179 requires two years of mathematics and one year of science and specifies no beginning date.

The Commission on General Education has approved the first change in ***Indiana*** high school graduation requirements in more than 50 years. Students entering school in the fall of 1985 will be required to take four years of language arts and two years of mathematics and science. A total of 19 units is required for graduation. Although computer education is not a graduation requirement, curriculum rules will require school systems to incorporate some form of computer literacy program or course into their Educational Improvement Program by 1984–85.

Kansas currently requires 17 total units for high school graduation with one unit required in mathematics and one in science. Beginning with the fall 1984 sophomore class, the Governor is recommending that high school graduation requirements be raised to 20 units, with two units each required in science and mathematics and a half-unit in computer literacy.

Graduation requirements for ***Kentucky*** high schools presently stand at two years each in mathematics and science, with 18 total courses required. This year the Kentucky State Board of Education approved an additional mathematics requirement and increased the total units needed to graduate to 20. For students graduating after 1986, three years of mathematics and science will be required.

High school graduation requirements in ***Louisiana*** are two years for science and three years for mathematics. The total number of units required is 22. No changes are currently being proposed.

Maryland requires 20 units for graduation, including two units of science and two of mathematics. Students must also pass a competency-based test to graduate. Under consideration are strengthening the requirements in mathematics and science and adding a requirement for computer education.

Maryland colleges and universities have recently raised admissions standards. Now required are three years of high school mathematics. The number of science units required remains two, but both must be laboratory courses and some institutions require one in biology.

In May 1983, the ***Massachusetts*** Board of Regents mandated an increase in the admission requirements to state colleges and universities: four units of English, three units of mathematics, two units of science and two units of foreign language.

Michigan schools set their own local graduation requirements. The state is piloting new graduation requirements in some districts this year that will call for two years each of high school mathematics and science.

While ***Minnesota's*** high school graduation requirements in mathematics and science are determined locally, a legislative study committee is examining the minimum number of hours spent in these areas. The State Board of Education will receive the committee's recommendations in November 1983, and legislation may occur in February 1984 that mandates requirements for graduation in mathematics and science and, possibly, computer education. The total number of units currently required for graduation is 15.

The ***Mississippi*** State Board of Education requires that students complete one unit of science and one unit of mathematics for high school graduation. The State Board of Institutions of Higher Learning has just approved more stringent college entry requirements. Students entering public colleges and universities will be required to complete three units of science and three units of mathematics.

Missouri requires 20 total units for graduation, including one unit of science and one of mathematics. Raising these requirements is under consideration. With requirements at their current level, statewide averages for high school graduates are two units of science, two units of mathematics and four units of language arts.

The current graduation requirements for ***Montana*** high school students total 16 units, including two units of science and two units of mathematics. In September 1983, the Montana Task Force on Science is expected to recommend to the Board of Public Education that the science requirements be increased to three units of science for the college bound and three units for junior high school students. Other recommendations include two hours of science instruction per week in grades K–3 and 3.5 hours of instruction per week in grades 4–6.

Beginning with the graduating class of 1986, ***Nevada*** high school students will be required to complete one year of science and two years of mathematics for graduation. Twenty total units are required for grades 9–12. Because graduation requirements were just recently upgraded, no further changes are being proposed at this time.

Currently, ***New Hampshire*** requires its high school graduates to complete a total of 16 units, including one year each of science and mathematics. The State Board of Education is drafting new secondary minimum standards. It is expected that beginning in 1984–85 students will need to complete two years of science and mathematics for a total of 18 units. Although New Hampshire does not have a computer literacy graduation requirement, the new secondary standards propose a half credit in computer literacy and that all schools offer a course in computer literacy in grades 9–12.

New Jersey students must complete one year of science and two years of mathematics to graduate from high school. Bills have been introduced into the legislature to strengthen these standards, but they have not yet passed.

Adopted by the ***New Mexico*** State Department of Education in April 1983, new graduation requirements include two units in mathematics and two units in science. These new requirements go into effect in the 1983–84 school year.

New York presently requires one year each in mathematics and science with 18 total courses required for a Regents' diploma and 16 total courses required for a local diploma. The state board is proposing a change in high school mathematics requirements to two years in mathematics to satisfy local requirements and three years of mathematics to satisfy Regents' requirements. All students must pass tests in reading, writing and mathematics through the Regents' Competency Testing Program before graduating from high school, a program which also has checkpoints in the lower grades to afford remedial help.

North Carolina requires high school students to complete two years each in mathematics and science. Twenty units are required for graduation. The State Board of Education is considering that an additional year in mathematics and science be required for graduation, raising the requirements in these areas to three years each in mathematics and science.

The University of North Carolina at Chapel Hill has strengthened its admission requirements. Requirements include two years of foreign language, one year of a laboratory science and three years of mathematics. Also recommended are four years of foreign language and calculus or precalculus.

The ***North Dakota*** Superintendent of Public Instruction has recently announced new graduation requirements. Students who graduate in 1985 must complete two units each of mathematics and science. Currently, students must complete one unit of mathematics and two of science. Students will be required to complete 18 total units for graduation in 1984, 19 in 1985 and 20 units in 1986.

In October 1982, the ***Ohio*** Board of Education revised its standards for high school graduation, increasing requirements from 17 to 18 units to include an additional unit of mathematics. Two units of mathematics and one unit of science will be required in September 1983. Although no computer literacy requirement is specified, the new standards encourage that every school with grades 7 or 8 offer a course that allows students to learn keyboard skills.

In 1982–83, ***Oklahoma*** instituted new graduation requirements: a total of 22 Carnegie units, including two units each in science and mathematics. This represents an increase of one unit in each discipline.

In ***Oregon*** one unit each of science and mathematics is required for graduation from high school. A total of 21 units is needed. No specific requirement for computer education has been established although it is being considered.

Pennsylvania's current high school graduation requirements include one year each in mathematics and science. Thirteen total units are required in grades 10–12 for graduation. Changes in graduation requirements are pending before the State Board of Education and would require 23 total units for graduation after 1984 in grades 9–12. Students would be required to complete three years each in mathematics and science for graduation. Computer education would remain an elective.

The ***Rhode Island*** Commissioner of Education has appointed educators to the Joint Committee on School and College Articulation to recommend new graduation requirements. The State Board of Regents recently approved 18 totals units for graduation. College-bound students will be expected to complete three years of mathematics, two years of science and one semester of computer literacy. These new requirements will affect the 1984 high school freshman class. A second phase of increasing minimum course requirements for college bound students entering high school in 1987–88 is being developed.

New ***South Carolina*** graduation requirements will be effective with the 1987 graduating class and implemented in the 1983–84 school year. Science will increase from one to two units and mathematics from two to three units. Students may take one unit of computer science to satisfy one of the mathematics units.

South Dakota presently requires one unit of laboratory science and one unit of mathematics with 16 total units required for high school graduation. The state board adopted a rule requiring two units of science (one of which must be a laboratory science) and two units of mathematics with a total of 18 units required for high school graduation by the year 1986. The South Dakota Board of Regents recently voted to require one-half credit in computer science for college admission beginning July 1, 1987.

The ***Tennessee*** State Board of Education has increased the total number of units required for graduation and the requirements for mathematics and science courses. Beginning with the 1983–84 school year, high school students must complete 20 total units for graduation and two years each in mathematics and science. No requirements have been established for computer education, although this is under consideration. The state board also requires high school students to pass the Tennessee Proficiency Test to receive a regular high school diploma. The test measures basic skills achievement in mathematics, spelling, language and reading.

The ***Texas*** Education Agency is presenting a proposal to the State Board of Education in October that would increase the total number of credits needed to graduate from high school from 18 to 20. The proposal also recommends increasing the mathematics requirement from two to three years and the science requirement from one to two years. These changes, if approved, will be effective in the 1984–85 school year.

The ***Utah*** State Board of Education is considering a number of proposals to change high school graduation requirements to include more courses in mathematics, science and other subjects. Modifications will take into account recommendations of the report, *A Nation at Risk*, and proposed college admission standards in the state that would require entering students to have two years of mathematics and two years of science.

Virginia presently requires one unit of science, one unit of mathematics and 18 total units for high school graduation. The State Board of Education has raised the requirements to two units each in mathematics and science plus one additional unit of mathematics or science to become effective in 1984–85. An optional advanced studies diploma will require three units each in mathematics and science and 22 total units for graduation.

In May 1983, the State Board of Education in ***Washington*** increased the total number of credits required for graduation, as well as those required in mathematics and science. Students beginning 9th grade after July 1985 must have a total of 48 credits, including 6 in mathematics and 6 in science. (A credit is equal to 60 hours of instruction; 3 credits are equal to a one-year course.)

The Governor has recommended that the Washington State Board of Education consider adopting the standards for high school graduation supported by the National Commission on Excellence in Education. These include three years each of mathematics and science plus one-half year of computer science.

West Virginia currently requires 20 units for graduation including one in science and two in mathematics. It is anticipated that the science requirement will be raised and some computer education will be required.

All ***Wisconsin*** high school graduation requirements are locally determined. Preliminary results of a study conducted by the Wisconsin Center for the Advancement of Science Education (CASE) show that many school districts are evaluating their science education programs and that at least 15 percent intend to increase their graduation requirements in science.

The Wisconsin Joint Council on College Preparation submitted a report, "Preparation for College," to the University of Wisconsin System Board of Regents in February 1983. The advisory statement identified the general competencies students should have at the beginning of college work and, in addition to other courses, recommended three required years each in mathematics and science for university entrance. Computer programming was mentioned as an "additional critical skill and experience." The Regents passed a resolution commending the recommendations. The Department of Public Instruction and the University of Wisconsin system have disseminated the report throughout the state.

IV. CURRICULUM GUIDELINES AND PERFORMANCE STANDARDS

Effective for the 1983–84 school year, a new science curriculum will be mandated in ***Alabama***. During the following school year a mathematics curriculum will be mandated. A basic computer awareness curriculum is already taught through vocational education classes.

In past years, the ***Arizona*** State Board of Education has mandated courses of study in grades K–8 for science, mathematics and other areas. In the spring of 1983, the legislature passed a law mandating the development of courses of study for all subject areas and all grades (K–12). The State Department of Education is currently working to implement this new mandate.

Arkansas has developed a Basic Educational Skills Continuum in mathematics, language arts and reading that serves as a curriculum guide in grades K–8 and as a basis for minimum performance testing.

California mandates curriculum guidelines for science (latest revision: 1983) and mathematics (latest revision: 1980). New guidelines will be issued in 1984. SB 813, signed into law in July 1983, requires the superintendent of schools to develop a course of study in computer education.

The ***Delaware*** State Department of Education in cooperation with local education agencies, has established a set of minimum performance competencies in the basic skills. It is the role of the local districts to set the performance level required for these competencies. Guidelines for the new mathematics and science credit requirements have been developed by the state and may be used at the local level.

By the 1983–84 school year, each school board in ***Florida*** must develop performance standards in K–12 academic programs in which credit toward high school graduation is awarded. Policies for student mastery of performance standards must also be established for credit courses. Appropriate methods for evaluating student mastery can include teacher observations, classroom assignments and examinations. The State Department of Education will provide *Proposed Student Performance Standards of Excellence* and technical assistance to the local districts to help them comply. By July 1985, the performance standards must be incorporated into the pupil progression plan for students in grades 9–12.

New legislation in Florida allows the Commissioner of Education, the State Board of Education or the legislature to enter into a consortium with other interested states for the purpose of developing and recommending strategies to raise the quality of instructional materials in the public schools.

The state of ***Georgia*** does not directly mandate curriculum guidelines. It has, however, developed a comprehensive, hierarchical list of essential skills and a curriculum framework in all subjects, grades K–12. It sets standards for schools which include instructional guidelines determined by the curriculum framework.

The ***Hawaii*** Office of Public Instruction provides curriculum guidelines, for grades K–12, in science, mathematics and computer education. The year of the latest revisions in mathematics is 1978; in science, 1981; and in computer education, 1983.

Each year since 1979 the ***Iowa*** Department of Public Instruction (DPI) has published updated versions of *A Tool for Assessing and Revising the Science Curriculum*, which is used by 4,000 teachers from 200 school districts. In 1982 the DPI published *A Commitment to Excellence—Directions for the 1980s*, which presents guidelines schools can follow in curriculum development and other aspects of mathematics programs. The *Iowa Plan for the Statewide Use of the Computer for Education*, first prepared in 1976, was updated in 1982; also in 1982 a statewide consortium (made up of representatives from local education agencies, area education agencies, and vocational schools) was organized to help implement the plan. Use of these guidelines and plans is not mandatory in Iowa.

The ***Kentucky*** Department of Education has published a *Teacher's Guide to Computer Courses* which is a curriculum guide to the introduction of computers as well as computer mathematics and programming.

Louisiana mandates curriculum guides for K–12 science and mathematics. The mathematics guides were updated during the 1982–83 school year, and nine separate science guides are available for grades K–12. Science guides were updated in 1983. Guides for computer education for all grades are currently being considered.

Mandated science guidelines were instituted in 1983 in ***Maryland***; guidelines for mathematics are being prepared and are expected to be in place in 1984; guidelines for computer education are in progress. In 1982–83 the state funded curriculum development grants to modify the curriculum framework for gifted science students.

Mississippi has adopted a program called Accountability/Instructional Management in grades K–12 as a basis for accountability and as a standard for accreditation. This program defines methods of instruction and evaluation and will provide the framework to implement the performance standards required by the recent Education Reform Act.

Missouri does not mandate curriculum guidelines but it does set curriculum objectives. In March 1983, teachers, education officials and members of the state Science Advisory Committee wrote objectives for ten areas of the elementary science curriculum that are intended to serve as models for school districts.

The ***Montana*** State Board, the Office of Public Instruction and the university system are developing curriculum guidelines for using technology in the classroom, including integrating the computer with existing courses as well as developing new courses. The university system is beginning to develop software to meet the needs of Montana schools.

Nevada mandates courses of study for K–12 science and mathematics. The courses of study, developed in 1974, are currently being revised. The Department of Education is working with superintendents and staff to evaluate and rewrite the guidelines. A first draft has been developed; a revised draft is due in October 1983. A curriculum for computer education will be suggested.

Senate Concurrent Resolution No. 55, passed in the last Nevada legislative session, directs the state universities and public high schools to work together to improve instruction in mathematics and other areas. University representatives are required to report annually to school districts and high schools the proficiency of high school graduates and "the extent to which the levels of competence necessary for college-level work have been achieved." The Nevada Department of Education and university representatives are directed to meet annually to develop a program for improving the competence of pupils in mathematics, reading and writing.

The ***New Hampshire*** State Department of Education has scheduled two groups—one for science and another for mathematics—to convene this fall to prepare a statement for each area on ***what*** should be taught and ***how*** it should be taught. Results of these two study groups will be disseminated to local districts to guide their curriculum development efforts.

The ***New Jersey*** Department of Education has developed mathematics and science K–12 curriculum improvement objectives covering curriculum review, revision and development of textbooks, teachers' manuals, parent booklets and technical assistance to local districts.

The 1980 *Guidelines for High School Graduation Requirements* set graduation standards for New Jersey students. The standards include: a statewide assessment test; explicit levels of proficiency in reading, writing and computational skills; guidelines for the development of graduation standards by local boards; and guidelines for remediation. In June 1983 the State Board of Education adopted a new 9th grade basic skills test that will be more rigorous than the minimum basic skills test it replaces.

New York has curriculum guidelines in grades K–12 in all areas of curriculum wih the exception of computer literacy. These guidelines cover a broad range of skills. The mathematics guidelines were revised in 1981, and the guidelines for science and writing are currently being revised.

North Carolina mandates curriculum policies for both mathematics and science, grades K–12. These policies were last revised in 1979. The State Board of Education recently completed detailed curriculum studies in science and mathematics. Computer literacy is not mandated; however, a state plan was developed in 1983 by the department of instruction and guidelines are available for district use. Higher order skills are being emphasized in the teaching of mathematics, science and computer education in all grades.

In October 1982, the ***Ohio*** State Board of Education revised the standards for elementary and secondary schools. The standards emphasize student achievement and strengthen high school graduation requirements. School districts will be required under the proposed standards to develop competency programs in the basic skills. Pupil performance objectives will be established by each district, and students will be tested for their competency at least once in the following grade groups, 1–4, 5–8 and 9–11.

The ***Oklahoma*** State Department of Education has mandated new curriculum guidelines for science and mathematics; implementation begins during the 1983–84 school year.

The ***Pennsylvania*** State Board of Education mandates curriculum guidelines for K–12 science, mathematics and computer education. These guidelines are being updated at the present time.

New ***South Carolina*** guidelines set by the Department of Education require school districts to offer a minimum of five mathematics units and five science units. This is part of the department's response to the $1 million appropriation that Governor Riley signed into law in June 1983 for training/retraining mathematics and science teachers.

South Dakota has developed standards of excellence in reading, mathematics and communication that include a focus on problem solving and critical thinking skills that can be enhanced through computer-assisted instruction.

In May 1984, the ***Tennessee*** State Board of Education adopted guidelines for developing computer technology courses in high schools. The guidelines cover introductory computer courses, computer programming and advanced placement computer science. It is expected that the guidelines will be reevaluated before courses are adopted as part of the high school curriculum. The state has mandated curriculum guidelines for K–12 mathematics and is developing guidelines for K–12 science courses.

In ***Texas*** a new state curricular framework, which includes essential elements of the 12 content areas identified by the legislature, is currently being developed. Use of this K–12 framework will be required for maintaining school accreditation.

Utah has no state-mandated performance standards for mathematics, science or computer education. The state education agency has, however, developed guidelines for mathematics and science. Competence in these subjects is required prior to graduation from high school; the measurement of competence is left to local districts.

The ***Vermont*** Department of Education is, through the Vermont legislature, proposing new performance and curriculum standards and guides in *all* subjects taught in Vermont schools. The department proposal, if accepted, will lengthen the school year by five days. Current curriculum guidelines suggest that four units of science and four units of mathematics be taught in grades 9–12, but districts decide how many units students must take.

Virginia specifies student performance objectives for each grade and each course in science and mathematics.

Development of competencies in education will begin soon in ***Washington*** state. In August, the superintendent will appoint an advisory task force to oversee the project. Mathematics has been chosen as the first subject to be addressed; science and computer literacy competencies are scheduled for development in 1984–85.

In ***West Virginia,*** learning outcomes for mathematics and science have been developed and will be verified in the next few months. the State Board of Education is expected to adopt these outcomes before January 1984 and incorporate them into curriculum guides for grades K-12. A competency-based curriculum guide for computer education has been developed for grades K–12.

The ***Wisconsin*** Department of Public Instruction is developing new K-12 curriculum guides for mathematics, science and computer literacy. The guides will serve as models not mandates. State advisory curriculum committees will be established to help department staff develop the guides.

To improve science and mathematics curricula in Wisconsin, the legislature will consider in its next session (October 1983) a proposal to establish a limited number of competitive grants for school districts to develop new curricula. The proposal will request $300,000 to be distributed among six school districts that have the potential to develop exemplary programs in mathematics or science. Three grants in mathematics and three in science will be distributed among small, medium and large school districts. Grants will average $50,000 and may be renewed if satisfactory progress is demonstrated.

V. SCIENCE AND MATHEMATICS PROGRAMS

The curriculum guidelines for mathematics that will be reissued in ***California*** in 1984 will streamline the presentation of high school mathematics, de-emphasizing some traditional material and emphasizing both the use of computers and the type of logic that aligns with computer logic.

The ***Colorado*** Minority Engineering Association sponsors a Mathematics, Engineering and Science Achievement (MESA) program in public and private schools in Colorado. The MESA program selects 7th-grade minority students and encourages them to stay in mathematics and science courses by providing tutoring and career counseling; students are also eligible for summer employment with industry or public agencies. MESA officials are assisting the Colorado Department of Education with minority programs for 1983–84 in mathematics, science and other areas.

The mathematics supervisor and the science supervisor at the ***Delaware*** State Department of Education provide technical assistance to local districts in the design and conduct of inservice training and in curriculum planning and development. They also represent the state education agency on a variety of local, state and national committees and task forces.

New legislation authorizes the Commissioner of Education in ***Florida*** to promote academic out-of-school learning activities sponsored by schools and community organizations. Mathematics, science and their application will receive special emphasis.

At Governor Orr's request, Project Primetime, a basic skills program for grades K-2 was recently given a six-fold increase in funding in ***Indiana.*** The program is designed to improve the skills of low achievers in mathematics, reading and language arts.

Under way in ***Iowa*** in 1983 with $6,500 from the state legislature and to continue next year with $40,000 in funding is a project that applies technology to improve the science curriculum and the teaching of science. This pilot program uses telephones and interactive computers to train biology teachers to teach physics.

In early 1983, the ***Kansas*** Department of Education created a committee to identify exemplary science and mathematics programs in the state. By spring 1984, the committee will establish the criteria for noteworthy programs and will share the features of selected programs with districts throughout the state.

Louisiana's Department of Education supports advanced courses in science for senior high school students. Funding comes from the gifted/special education budget and from school districts. Advanced science courses are available during the summer for students in grades 6–8. Advanced placement programs are being emphasized; secondary students receive college credit if they pass advanced placement examinations.

The ***Massachusetts*** Department of Education has set up a clearinghouse for science, mathematics and computer education, scheduled to begin in the fall of 1983. The clearinghouse will provide teachers and school districts with information on successful programs, preservice and inservice training/retraining opportunities, public-private partnerships and coordination of joint efforts to improve quality and exchanges of personnel among districts. A proposed computer resource bank in mathematics, science and instructional technology would provide information about curriculum materials, consultants, hardware and software.

The ***Nebraska*** State Education Association contracted with Nebraska Instructional Television to develop programs based on computers. "Think About" is a program on decisionmaking for 5th graders and "Math Wise" is a program that enhances problem-solving skills.

The ***New Jersey*** Department of Education is currently identifying exemplary programs in science and mathematics across the state. The project will develop a data base on model programs to share with local districts.

Under its Master Plan for the Improvement of Mathematics and Science Education, the ***North Carolina*** State Board of Education is proposing funding of $240,000 to establish programs of excellence in mathematics and science. Eleven secondary schools will be selected to provide examples of excellence for other school systems. The objectives of the mathematics and science programs are to improve student attitudes toward these courses, raise enrollment, improve student performance and increase the number of students entering postsecondary mathematics and science programs.

The North Carolina Council for Minorities in Science, Mathematics and Engineering is identifying talented minority students in grades 5–7. The state-level council networks with local businesses to track students over time and provide them with long-term assistance. Students are selected into the program based on their interest and grades in school and also upon the recommendations of principals, teachers and others. The long-term goals of the program are to provide students with summer employment, role models and college support.

Many ***North Dakota*** schools are considering using a number of innovative programs in science and mathematics classes. Examples include an NSF project, "Sci/Math," and Project CLIMB. A calculator mathematics program has been developed to supplement the junior high school mathematics program. Computeronics, designed for gifted students, is currently used in two schools and will be expanded to 17 schools this year.

Recent curricular efforts in ***Pennsylvania*** include the use of audiovisual media for science education and a full year program in nuclear science for secondary students. A model computer literacy course for students has been developed by the Department of Education and piloted in 20 school districts. The goal is to have every student take the course before graduating from high school.

Tennessee's Basic Skills First program is a new elementary curriculum in mathematics and reading. The teacher-designed curriculum establishes 1300 skills children should learn between kindergarten and 8th grade. The program proposes that by 1990, every nonhandicapped child should pass a basic skills competency test before entering 9th grade.

The state office of education is working collaboratively with ***Utah*** Universities to develop two programs. One program would retrain mathematics and science teachers at summer institutes using computer-assisted instruction. The other program would provide direct instruction to students using master teachers and a telecommunications network that is now being set up in Utah.

Governor Richard A. Snelling of ***Vermont*** has initiated the Early Childhood Program for children aged 3–8. The program, which began in 1983–84, strongly emphasizes the early introduction of science and mathematics.

During the summer of 1983, the Governor's Institute on Science in Vermont sponsored a computer problem-solving contest for about 35 students selected by statewide committee. With the Math League, the Institute sponsored a mathematics contest.

Washington's High Technology Education and Training Act, also passed this year, included support for mathematics, science and computer education programs for students and computer technology inservice training for teachers. Funding will be available over the next two years, primarily for student activities.

West Virginia's Bureau of Learning Systems, which recently examined results of the State County Testing Program for the last six years, noted that performance had improved markedly, but key curriculum and instruction adjustments were needed. Included among the major findings of the study, "Academic Achievement of West Virginia Students as Measured by Comprehensive Tests of Basic Skills," were the following: (1) across all grade levels, mathematics instruction should put less emphasis on merely solving mathematics problems and more emphasis on using mathematics to solve real-life problems; (2) improvements may be lagging at high school levels in science achievement because students simply lack interest in the subject; the current emphasis on content should be balanced with hands on and problem solving activities.

In October 1982, a conference was held at the Wingspread Center in Racine to establish a model for science education in ***Wisconsin.*** The science educators attending the conference made recommendations aimed at increasing science achievement for secondary students through raising high school graduation requirements, updating curriculum, developing new levels of public support for science education and broadening career awareness.

The first annual Science World, piloted by the Department of Public Instruction and the Wisconsin Academy of Sciences, Arts and Letters, was held July 10–16, 1983. Science World is a summer camp designed to motivate junior high school students to pursue specialized secondary programs and to consider careers in science and technology. Science teachers selected for excellence lead teams of students in laboratory and field investigations. In addition to seven hours of immersion in science and technology daily, students meet with scientists and technologists from the university community and business and industry. Forty eighth grade students participated in the 1983 pilot project; as many as 360 young people may participate in 1984 if funding is made available.

VI. COMPUTER EDUCATION PROGRAMS

The Governor's Interim Commission (March 1983) proposes that the state of ***Alabama*** provide $10.2 million to local education agencies for the purchase of 4,000 microcomputers for elementary and secondary schools and for teacher training workshops. Staff at the Alabama Department of Education provide assistance to local districts in the review, evaluation and selection of education software.

The Alabama Council for Computers in Education, representing K-12 teachers, is primarily a clearinghouse and communications organization for the Alabama local education agencies.

The ***Alaska*** Office of Educational Technology and Telecommunications (OET&T) was formed in 1981 by combining the Educational Telecommunications for Alaska Project (ETA) and the Office of Educational Technology and Telecommunications, which contained Alaska's Instructional Television unit. The goal of the office is to design, develop and implement applications of technology to education for specific education needs. The Learn/Alaska Television network includes statewide video and audio conferencing services as well as 150 different TV series covering a wide range of subject matter. The network is received in over half of the cities and towns in Alaska and is on the air 18 hours a day, 7 days a week for viewing both in school and at home.

Alaska's Office of Educational Technology provides credit for computer-based high school courses. The Individualized Study by Technology (IST) is designed for self-directed, self-paced student learning and requires little teacher preparation time.

In April 1983, Governor Babbitt signed SB 1187 to allow the ***Arizona*** Department of Education to operate a clearinghouse of information on instructional software. The department will provide information to the state school board and local school boards and help them coordinate bulk purchases of highly rated software. The department will also recommend software criteria for school use. One component of the software criteria will be evidence that the software is effective in improving learning.

The 1983 session of the Arkansas General Assembly passed Act 528 which authorizes a pilot program using computer technology to teach basic skills. State and private industry will work together to develop the program. The Instructional Microcomputer-Based Program for Arkansas Children (IMPAC) will identify specific coursework, develop a staff training component and field test the programs at grades 4–6 in 12–20 Arkansas schools.

Colorado has joined two educational computing networks, the Minnesota Educational Computing Consortium (MECC) and the University of Wisconsin project (WIS). As an institutional member of these two projects, the Colorado Department of Education provides local districts with access to software and new curricula on computer literacy. The department sponsors workshops to train district personnel in the use of classroom computer materials.

The State Board of Education in ***Delaware*** has recommended to all school districts that a nine-week computer education course be incorporated into the high school curriculum and that all college bound students take at least one course in computers.

The Delaware State Council on computer Education, located in the state education agency, is a statewide educational and coordinating body. Established in 1973, it initially provided advisory services to the state board of education. In 1979–80, the council's role changed to one of coordination, promoting the compatibility of microcomputer hardware systems in the local education agencies. The council began reviewing and approving local district purchases of computer hardware and software. Under this system, local education agencies must demonstrate that they have reviewed their needs and must state their intended use of microcomputers prior to approval for acquisition. The council also provides computer literacy workshops for teachers and is now expanding into the development of computer literacy courses for students.

Project Direct, a Delaware network linking all public schools, provides instructional computing services. Funding for the consortium which comes primarily from user fees and state department aid, supports field staff who work with teachers in helping them to employ computers in the classroom.

Each spring the State Council on Computer Education, along with the Delaware Council of Mathematics Teachers, local universities and the Delaware Council of Science Teachers, sponsors a Computer Fair. This two day event includes displays, workshops and demonstrations for parents, students, teachers and the general public. Highlights of it are computer programming and calculator contests for school-age children and youth in grades K-12.

The ***Florida*** Legislature appropriated supplemental funds of $30 million to increase students' exposure in grade K-12 to laboratory experiences in mathematics, science and computer education. Ten million dollars have been earmarked for local districts to expand computer-assisted instruction in mathematics and computer literacy in grades K-12. Eighteen million dollars have been set aside to build or renovate science laboratories; another $2 million is allocated for laboratory equipment and supplies in grades 9–12.

A consortium of 60 ***Georgia*** superintendents is working with the State Department of Education to operate a technology center in Macon. The center (created in the aftermath of two successful technology fairs) will be housed in a vocational school. It will evaluate hardware and software, run workshops and train teachers and administrators. If the center is a success, others will be located at other vocational schools.

In 1983, the ***Hawaii*** Office of Public Instruction launched a seven-year plan to advance computer education. This plan includes the development of courses in computer literacy, computer-assisted instruction and computer-managed instruction. The plan offers an "exploratory" computer curriculum for all students, K–12, a more advanced computer curriculum in secondary education and a second computer curriculum emphasizing vocational education applications. Up to this point, computer-assisted instruction has been used only to teach basic skills, although wider applications are being planned. The Office of Public Instruction plan calls for inservice training of 250 teachers this year and 1,000 teachers during the next year.

Computer workshops are provided by the Hawaii State Education Agency, and pilot programs include Advanced Placement Computer Science, the K-6 Exploratory Computer Literacy Program and the 7-12 Exploratory Computer Literacy Program. The computer science curriculum framework is in draft form, as are the curriculum guides for the K-6 and 7-12 computer literacy programs. The Hawaii legislature recently funded a special project which provides local education agencies with monies to purchase hardware and software. The project, Exploratory Computer Awareness Interim Program, provides computer experience for all seniors.

SB 124 authorizes the ***Illinois*** State Board of Education to make grants to school districts and regional superintendents for equipment, software and training. The grants will assist districts in developing computer literacy programs and upgrading computer awareness in the schools. The bill was sent to the Governor on July 18, 1983, and is one initiative within the Larger Computer Consortium program.

In Illinois HB 997 authorizes school boards to sell or market any computer program developed by a teacher as a result of the teacher's duties with the district or the use of school resources or facilities. The bill allows both parties to enter into a contractual agreement in marketing the program. Both legislative houses passed the bill on June 28, 1983, and it has been sent on for the Governor's approval.

Iowa supports (although it does not operate) the Iowa Educational Computing Consortium. Members of the consortium are the 15 area educational agencies and vocational/technical community colleges. One activity is arranging for group purchases of computer hardware and software. Iowa has an institutional membership in the Minnesota Educational Computing Consortium (MECC) that gives it access to MECC's software library and allows it to duplicate and distribute software throughout the state. A project at the University of Northern Iowa's Price Laboratory School will integrate microcomputers into the middle and high school mathematics curriculum.

In progress is an effort, initiated by the Iowa State Department of Education and funded with $250,000 from the state legislature (through House File 532, a major education bill that became law in May 1983), to establish a computer software clearinghouse in Iowa by July 1984. The coordinating committee that will oversee the clearinghouse is working to develop a "Request for Proposal" for the establishment of the clearinghouse. HF 532 makes several other important provisions for mathematics, science and computer education in Iowa.

In 1981, 1,500 microcomputers were in use in more than half of the ***Kansas*** school districts. In 1982, the Department of Education created its own Education Assistance Section to assess state computer education needs, provide microcomputer inservice training and evaluate software.

The ***Kentucky*** Department of Education has taken a leadership role in serving local school districts to implement computer literacy courses. These services include workshops for local districts to assist teachers in the effective use of computers. Most of Kentucky's vocational schools have computers installed in their business and office programs. Also, local districts that participate in gifted programs often choose to spend their time and money in computer education.

Louisiana provides financial assistance to local parishes for the purchase of computer equipment. During the 1982–83 school year, $180,000 was allocated to ten elementary schools across the state in increments of $18,000 apiece. Computers, peripheral equipment and software were purchased with the funds. The Management Information System (MIS), a department of education agency, reviews and evaluates software. MIS also sponsors conferences on computer literacy.

The section on Gifted Services of the Louisiana Department of Education began a program three years ago to spread computer literacy to teachers and students across the state. The program has provided workshops and created a computer telephone network for a successively larger number of teachers each year. The 232 teachers who have joined the program work with gifted student programs in every parish of the state.

Massachusetts computer education programs will be enhanced by new state initiatives, including a clearinghouse (fall 1983), a proposed computer resource bank, and a proposed software advisory service.

The ***Minnesota*** Educational Computing Consortium (MECC) is a cooperative venture that provides the state's 435 school districts with access to a timeshare system, discounts on microcomputers, a lending library of educational courseware and inservice training for teachers. The Minnesota State Department of Education is working with MECC to develop and review commercial software. The state department recently developed and disseminated a document, "The Use of a Computer to Help Teach the School Curriculum." MECC encourages other states to become members of the consortium.

The Minnesota Education Technology Act, passed in May 1983, appropriates $5.7 million to improve the use of technology in elementary and secondary schools. School districts are encouraged to develop written technology utilization plans and will receive state aid if the proposed plan complies with the legislation. Districts that receive approval on their plans will receive additional funding for inservice training and technical assistance from the Minnesota Educational Computing Consortium (MECC). By January 1984, the state board will designate from 8 to 10 districts as technology demonstration sites and award each district a grant for use during the 1983–84 and 1984–85 school years.

The Minnesota Department of Education will receive $200,000 to compile, publish and distribute to school districts a list of high quality courseware packages for use in public elementary and secondary schools. The funding is part of the Minnesota Education Technology Act, passed in May 1983. The department will update the list every six months. An additional $1.1 million will be available to school districts to subsidize courseware packages that qualify as high quality.

In May 1983, the Minnesota legislature appropriated $250,000 to the Minnesota Educational Computing Consortium (MECC) to develop and design courseware packages to meet school district needs which are otherwise unavailable or too expensive to purchase. The department of education will evaluate the courseware packages and MECC is authorized to sell the courseware to other states.

In the spring of 1983, the ***Missouri*** Department of Elementary and Secondary Education sponsored three conferences on the use of the computer for instruction. Missouri is a member of the Minnesota Educational Computing Consortium and a strong supporter of the Agency for Instructional Television (headquartered in Bloomington, Indiana). The agency is now moving into software with the development of eight interactive software/video packages.

Computer courses are available in some of ***Nebraska's*** schools, with regional science, mathematics and computer programs available to high school students through colleges and universities.

The ***New Mexico*** Computer Users Consortium was formed recently to develop curricula and provide workshops and inservice training programs.

In 1980, the ***New York*** State Education Department initiated a "futuring" project which resulted in a core program to be recommended as a mandate for all K-12 students. The core program includes learning about computer technology. Although a state mandated curriculum in computer literacy does not yet exist, the State Department of Education provides technical assistance in computer education and software evaluation. New York has regional centers for teacher and student computer training.

In New York, the Division of Occupational Education appointed a statewide committee to examine future occupational opportunities. Computer-related technologies are part of a core program in occupational education.

The New York State School Computer Services System is a state-sponsored program to promote local school district use of computers in conducting administrative activities. Recent proposals, developed to meet the needs of teachers in computer literacy, have been submitted to the New York State Education Department for funding.

In January 1983, the ***North Carolina*** Department of Public Instruction released a state plan for computer use in the public schools. Among its other recommendations, the department urges the use of microcomputers as an instructional tool for all content areas and grades and the development of opportunities for all students to become familiar with computer operations. The state department assists local districts by providing workshops, hardware contracts, a computer laboratory and technical consultant services.

The ***North Dakota*** Department of Public Instruction has established a separate computer section and broadened the mathematics, science and computer areas in the *Guide for Curriculum Planning*. Computer education courses must fit into one of three categories (literacy, programming or advanced programming) and be approved by the department for students to receive credit.

The North Dakota State Computer Committee is currently working on a plan to suggest directions schools should follow in using and integrating the computer into the classroom.

North Dakota has purchased membership in the Minnesota Educational Computing Consortium (MECC), enabling local districts to purchase software at reduced prices. The agency has also secured bids for group microcomputer purchases at reduced prices.

The ***Ohio*** Department of Education has a new handbook that describes a process for integrating the use of microcomputers into the classroom. The handbook is a step-by-step guide to establish a district-level computer use committee, select hardware and software, establish inservice programs and identify other resources.

Ohio has established Basic Education Skills through Technology (Project BEST) to build an interstate communications network. The objectives of Project BEST relate to several of the priorities set by the State Board of Education in *Mission of the 80's: A Blueprint for Excellence*. The objectives include improving basic skills, improving curriculum and providing vocational education that includes basic skills. As part of this project, the State Department of Education is compiling a directory that describes resource persons and programs in Ohio.

The ***Oklahoma*** Department of Education has a new Microcomputer Instruction Section, which consults and advises local districts in hardware and software selection. The Department of Education provides inservice workshops for teachers throughout the state in science, mathematics and computer education. Three computer camps are organized at East Central State University in Oklahoma, all of which offer courses on awareness, literacy and programming.

The ***Oregon*** Educational Computer Consortium (OECC) includes approximately 95 local education agencies and has been evaluating and selecting software for the past two years. The Agency for Instructional Television (AIT) has produced "Solutions Unlimited," a video/computer problem solving skills development program. The Oregon Department of Education participates in the Minnesota Educational Computing Consortium (MECC), Project BEST, the U.S Department of Education's Information Network and will be involved in the Region X Department of Education's Computer Literacy Project.

Pennsylvania participates in a statewide computer network, PENNLINK, which links the State Department of Education, intermediate units and local districts. The department's information center offers training courses in hardware and software for its staff.

The ***Rhode Island*** Governor has undertaken a state initiative that will put $8 million in resources over a two-year period to bring microcomputers into every public school. Of the $8 million, $3 million will be spent on elementary and secondary schools, $1 million on vocational and technical schools and $4 million on public institutions of higher learning. For elementary and secondary schools, the state will pay 60 percent of the total cost and the local district will furnish 40 percent. The state will cover the 10 percent of the total cost reserved for teacher training. State aid will reimburse local districts for up to 75 percent of their 40 percent match. The program will help train Rhode Island students for the jobs of tomorrow. The initiative is designed to increase computer literacy in Rhode Island, enhance the education system and act as a strong drawing card for prospective employers.

Computer Skills Next introduces ***Tennessee*** students in grades 7 and 8 to a new computer curriculum. The curriculum plan calls for 15 hours of computer literacy training in each grade for a total of 30 hours of classroom instruction, which will be mandated in the 1985–86 school year. The State Board of

Education has recommended that components of the plan (including teacher training, hardware and software purchases and technical assistance for local schools), be funded by the Tennessee General Assembly. The program has been piloted in 14 schools. One-third of all junior high and middle schools will participate in an incentive pilot program beginning January 1984.

The Director of Computer Technology at the ***Texas*** Education Agency provides information and technical assistance to local districts on the design, development and implementation of computer-based instruction and management systems.

The Texas Education Agency funds the Texas Education Computer Consortium which includes six educational service centers. The consortium's primary focus is the development of computerized management information systems. Schools in the consortium have access to orientation and training sessions related to computer use.

The state education agency in ***Utah*** has a working group in technology that is studying issues of computer-assisted instruction and computer management systems. This group is assisting in the establishment of a statewide Microcomputer Information Laboratory that will give school districts an opportunity to evaluate hardware and software and will train teachers and administrators. The state education agency technology group is also assisting in the development of a statewide consortium of computer users in education. Through this consortium, information on users, hardware and software and other topics related to computer technology will be made available. A long-range objective is to establish a statewide computer network.

The ***Vermont*** Department of Education has published the first of a series of booklets on computer education. *Computer Considerations for Vermont Schools* outlines the state's computer education philosophy and provides a curriculum matrix showing computer applications in grades K-12.

The ***Virginia*** legislature recently appropriated $280,000 to assist school districts in purchasing computer equipment. The appropriation is in addition to a tax incentive bill that encourages businesses to donate computer equipment to the schools.

The Virginia State Leadership Assistance for Technology in Education Project maintains a software review and evaluation center at the state department of education and offers staff development programs for local districts in computer usage.

Washington's High Technology Education and Training Act, passed in 1983, includes state funding for K-12 student programs, inservice training, the establishment of regional computer demonstration centers and technical assistance staff at each educational service district and in the office of the superintendent. Over the next two years, funding will be available for student mathematics, science and computer education. A small portion of this amount will fund inservice training. The regional computer demonstration centers, which are to be operational by the fall of 1983, will be managed by people who have computer backgrounds or who have used technology in the schools. The centers will serve the entire state and allow districts to review hardware and software before making purchase decisions, serve as training sites for teachers and administrators and provide technical assistance and consultation to school districts in computer/technology education. Finally, part of the Act's funding will support two professional staff at the office of the superintendent. The staff will provide technical assistance to local districts, the educational service districts and the state education agency and will administer the K-12 programs.

The Washington Office of Public Instruction through the educational service districts, conducted 25 orientation sessions for school district personnel on the use of a handbook developed by the Computer Technology in Curriculum and Instruction Task Force. This interdisciplinary group, convened by the superintendent of public instruction, produced and disseminated a manual that includes information and suggestions for developing plans to acquire the necessary equipment and materials to begin using the computer. Software evaluation, staff development and available resources (organizations, publications, etc.), are addressed in the handbook. A directory of local educational agencies in the state that use computers is also included.

Microcomputers are used for instruction in every county in ***West Virginia.*** Their purchase and use increased 200% within the past school year, according to a statewide department of education survey completed in April 1983. This increased availability, along with other factors including computer literacy requirements recommended in the state's master education plan, prompted a recent appropriation by the legislature for the development of a computer network. In June, at the request of Governor Rockefeller, over a million dollars was appropriated for the network, which will eventually include all of the state's public schools.

West Virginia is one of four states participating in a research study conducted by the Appalachian Regional Education Lab. The study will determine if 9th and 10th graders can use microcomputers to remedy basic skills deficiencies.

The West Virginia Department of Education was instrumental in the design, development and implementation of a computer-assisted mathematics laboratory now operational in one local school district. The lab has provided much information about the effectiveness of educational software. The department is currently disseminating information to local districts about this and other topics related to computer technology in the classroom.

Wyoming is a member of the Minnesota Educational Computing Consortium (MECC) which allows each district the opportunity to purchase MECC materials and services. The state also participates in Project BEST and its teleconference activities. Wyoming provides each school district with membership to the Math-Science Teaching Center located at the University of Wyoming. The center has a software library available to members.

VII. SUMMER INSTITUTES, MAGNET AND RESIDENTIAL SCHOOLS

The ***Arizona*** legislature recently appropriated $50,000 to the Board of Regents to establish mathematics and science centers at state universities for outstanding high school students. The centers, which are operating this summer at three universities, coordinate coursework and counseling in cooperation with high school teachers. Students are selected on the basis of merit and need, and some funding is supplied for tuition and living expenses.

SB 813, signed into law in ***California*** in July 1983, targets funds for the development (1984–85) of specialized high schools in high technology and the performing arts. SB 813 also calls for the establishment of summer schools in mathematics, science and other critical academic areas.

For the past four years, the ***Delaware*** Department of Education and the E.I. DuPont Company's Committee on Educational Aid have sponsored a three-week summer institute in mathematics and verbal skills and computer programming for outstanding 8th grade students who qualify in the Johns Hopkins Talent Search. Parents pay part of the cost of this program which includes an opportunity for students to use computers.

The Governor's School for Excellence, a one-week residential summer program at the University of Delaware, is designed to recognize outstanding students in both public and private schools who have completed 10th grade. Participants are chosen on the basis of academic achievement and leadership abilities. It is hoped that through this experience, students' high motivation will be reinforced so that they can have a positive effect on their peers during the next school year.

Recent legislation allows the ***Florida*** Department of Education to award grants to public school districts, higher education institutions and science museums and centers to conduct summer camps for students in mathematics, science or computers.

The Governor's Honors Program in ***Georgia*** has strong science, mathematics, and computer components: "rising seniors" and recent graduates attend six-week summer sessions at North Georgia College (200 students) and Valdosta State (400 students) that provide an intensive three-day experience with computers before students move into their special interest areas (in all subjects).

The State Department of Education in Georgia provides consultation to school districts that develop magnet schools. About 25,000 students are now enrolled in magnet schools, which are organized for the most part around mathematics, science, the arts, the humanities or international education.

SB 338, which has passed both houses and been sent on to the Governor of ***Illinois,*** appropriates $800,000 to establish summer institutes for gifted students and teachers. The institutes will emphasize mathematics, science and computer technology; they will be conducted by the Illinois State Board of Higher Education. The board will provide traineeships for talented undergraduate mathematics and science students and will award fellowships to graduate students who are interested in working with gifted children.

HR 328 directs the Illinois State Board of Education to investigate the feasibility of establishing the Illinois School of Science and Mathematics. Students with high aptitudes in these subjects would attend the residential high school. The state board will report its recommendations by March 1984.

Kentucky began in 1983 a Governor's School Program at Centre College for 250 high school juniors to study "Science, Technology and Kentucky's Future." Those students selected will attend this program through state funding. The approach will be theoretical rather than technical and is intended to proceed beyond the instruction given in secondary schools.

The state-supported ***Louisiana*** school for Mathematics, Science and the Arts is located in Natchitoches on the Northwestern State University campus. The school is patterned after the North Carolina School of Science and Mathematics and accommodates 700 11th- and 12th-grade students. The first class, composed of talented students nominated by school systems, will enter in September 1983. A full curriculum in computer education will be offered.

Maryland supports numerous one and two-week summer institutes for gifted students (grades 5-12) that are held on college and university campuses, at science museums and at other institutions around the state. The program is large; mathematics, science, and computers are among the subjects taught (total enrollment in these subjects in 1983 is 1,325) but other areas are covered as well. Applicants are screened by selection committees on the basis of achievement tests, teacher recommendations and a student essay describing special training, honors and interests. Courses offered include, for example, aquatic biology, environmental science, problem-solving, computer programming, computer-oriented mathematics, advanced topics in mathematics, physics, energy, optics—and even a space science course taught at NASA. The state department of education runs the project and pays for at least 50 percent of costs; parents pay a registration fee, as well as some room-and-board expenses for residential two-week courses.

Michigan has many summer enrichment programs for gifted students in computers, mathematics and science developed by and held at state colleges and intermediate school districts. Some of Michigan's larger school districts have magnet schools with mathematics and science components. The state board of education cosponsors with selected universities a two-week summer institute for the arts and sciences for talented high school students.

Summer institutes in ***Mississippi*** offer enrichment programs to high school students at Jackson State University and the University of Southern Mississippi.

Mississippi has a Governor's School at the Mississippi University for Women in Columbus. Juniors in high school must be nominated by their schools to gain admission. The Governor's School offers a balanced enrichment program in all curriculum areas.

The ***Nebraska*** Scholars Institute at the University of Nebraska in Lincoln is a two-week enrichment program in its first year. It offers mathematics, science and other courses to 200 gifted high school students.

New Jersey is beginning a three-year plan to open new Governor's schools. The Governor's School of Global Studies, the result of a public-private partnership, will open in the summer of 1983 at Monmouth College. Participants are 100 high school juniors and seniors chosen on the basis of their scholastic records. In 1984, a Governor's School of Science and Technology will open.

During the summer of 1983, the ***New Mexico*** Department of Education provided a science-mathematics seminar for high school students at Highlands University.

The ***North Carolina*** School of Science and Mathematics, located in Durham, is a state-funded, public school that brings roughly 400 gifted 11th- and 12th-graders to its residential campus. The school was established in 1978 by the General Assembly and receives additional support from industries and foundations. The 1983 budget is $3.3 million. Students are selected on the basis of their mathematics and science aptitude and contribute to their tuition and board costs through work and service in the school and community. A distinguished faculty of highly skilled individuals and consultants from industry and education provides an enriching atmosphere for the students.

Two Governor's Schools in North Carolina offer summer residential programs for gifted junior and senior high school students. Their purpose is to assist gifted young people achieve their full potential, to encourage schools to establish and improve programs for gifted students, and to train teachers to teach gifted students. The Governor's School West is located in Winston-Salem; the Governor's School East is at St. Andrews Presbyterian College in Laurinburg. Four hundred students participate at each campus. Students are nominated by local school districts. The schools offer a wide variety of courses, including mathematics and science.

The ***Ohio*** Department of Education, in cooperation with a major state university in Ohio, sponsors a one-week School for the Gifted each year. About 60 gifted high school juniors undertake academic and artistic pursuits at a level beyond that possible in most of their hometown high schools in a week of lectures, hands-on activities, field trips and performances.

The ***Pennsylvania*** Governor's School for the Sciences has been established at Carnegie-Mellon University with state funding and support from Pennsylvania foundations. In 1983, the school accommodated 60 students about to enter their junior and senior years in high school. Future programs will attempt to expand the number of students. The school emphasizes mathematics, science and technology and offers guest lectures by international speakers. Students are selected solely by ability, as determined by teacher recommendations, SAT scores, grades and other measures. The State Department of Education piloted the project in 1982.

The ***Rhode Island*** legislature established a commission in May 1983 to determine the feasibility of starting a magnet school in science, mathematics and computer education. The State Department of Education will report to the legislature early next year.

Over the past four years, the ***South Carolina*** Governor's School for Science, Mathematics and Computer Science has provided summer programs for gifted and talented students. Students are selected on the basis of demonstrated abilities and capabilities. Funding for the school comes from state appropriations, supplemented by tuition and private scholarships.

South Dakota provides summer programs funded by state and private sources for the enrichment of high school students in mathematics and science and other areas.

As part of the ***Tennessee*** Better Schools Program, residential summer schools for gifted or talented juniors and seniors are being proposed. The schools would serve several hundred students in science, mathematics and the performing arts. If funding for the schools is approved, the program would be administered through the state's special education program.

VIII. RECOGNITION AND AWARDS

The ***Alabama*** Interim Commission on Science and Mathematics in Elementary and Secondary Schools has proposed developing recognition programs for outstanding teachers and students.

Beginning with the 1983-84 school year, the ***Arizona*** Department of Education will sponsor an Academic League to foster competitive academic events. The program will include competitions in mathematics and science as well as in other subjects.

SB 813, which became law in ***California*** in July 1983, institutes Golden State High Achievement Tests for high school seniors to obtain honors at graduation. It also funds a pilot program to reward high schools for improving student academic achievement (1984-85).

Each year the ***Delaware*** state education agency cosponsors (along with the Delaware Council of Teachers of Mathematics) mathematics leagues for elementary, junior high and senior high school students in public and private schools. There are regional and state winners and a mathematics league banquet.

Computer programming and calculator contests for school-age children and youth are held each year at the State Computer Fair which is sponsored by the Delaware Department of Public Instruction, the State Council of Mathematics Teachers, local universities and the State Council of Science Teachers.

The Delaware State Department of Education and Johns Hopkins University sponsor an annual talent search among public and private school students in the 7th and 8th grades. A test is administered and those who meet the criteria are invited to a special Talent Recognition Ceremony.

The ***Florida*** Academic Scholars Program has been initiated to recognize and reward outstanding performance and academic achievement of public and nonpublic school students. The Commissioner of Education will make this award beginning with the 1983-84 school year to all students who meet the requirements which include: four years of progressively advanced instruction in language arts, science and mathematics; three years of instruction in social studies; two years in a foreign language; and one year in either art or music and physical education. Students must meet other state board requirements as well.

The ***Georgia*** Scholars Program, begun by the State Department of Education in 1983, recognizes the achievement of graduating seniors who have high test scores and a 3.75 grade average, have completed a rigorous program (including three units of science and four of mathematics) and have been leaders in extracurricular activities. Excellent teachers will be identified in 1984, excellent schools in 1985 and excellent school systems in 1986.

This year ***Minnesota*** schools will receive $641,000 in state categorical aid to support programs for gifted students in science and mathematics. In addition, $5.7 million has been appropriated for computer aid to the schools.

The Minnesota Academic Excellence Act, passed in May 1983, creates a foundation to promote academic excellence in Minnesota public schools through public-private partnership. The Academic Excellence Foundation will advance programs of recognition and awards for students demonstrating academic excellence; summer institute programs for students with special talents; recognition programs for teachers, administrators and others who contribute to academic excellence; summer mentorship programs with business and industry for students with special career interests and high academic achievements; Governor's awards ceremonies to promote academic competition; and consider the establishment of a Minnesota high school academic league. The legislature appropriated $150,000 to develop the foundation. Additional funds will be sought from private sources.

The ***North Carolina*** Scholars Program is a state-supported program for gifted students in the public schools. The program encourages secondary students to take a heavier load of rigorous courses prior to graduation. Two plans of study are available to students. Both require students to complete 22 total units for graduation; however, in the first plan the emphasis is on mathematics and science, requiring students to complete four years of mathematics and three years of science. The second plan is a well-rounded selection of various learning areas. Students apply to their local districts to participate in the program and selection is performed locally. A Scholars' Program brochure will be available by late summer, 1983.

Tennessee high school seniors who are selected for recognition in the Tennessee Honors Program receive public recognition and a certificate of merit from the Governor and the State Department of Education. Students are nominated by their principals in one of eight scholastic categories, including science and mathematics. Students are judged by two committees on the basis of grade point average, class rank, performance on standardized tests and other criteria.

This year the Governor of ***Utah*** designated a mathematics and science week during which outstanding teachers in those disciplines were honored.

The ***Washington*** Office of the Superintendent for Public Instruction participates in the President's Awards for Mathematics and Science, a nationwide program to recognize outstanding mathematics and science teachers in grades 7 to 12.

The Washington State Mathematics Council sponsors regional mathematics contests annually for high school students and conducts a competition to determine the state winner. The Washington Scholars Program recognizes the accomplishments of three graduating seniors from each legislative district. Students are nominated by their high school principals chosen on the basis of their academic achievements, leadership abilities and community service.

West Virginia is currently participating in the President's Awards for Mathematics and Science, a national program with established standards for recognition. The Department of Education has great interest in developing other awards programs and opportunities for recognition such as science fairs, competitions and institutes.

IX. REGIONAL CENTERS

The ***Florida*** Department of Education is authorized to award grants to public school districts and to public and private postsecondary institutions to establish five regional centers of excellence in mathematics, science, computers and technology. Regional centers will aid in the development and dissemination of new instructional strategies, the recruitment and training of minority and female students for technical careers, and the operation of a computer education laboratory and library. Two hundred thousand dollars has been appropriated to begin the development of the first two centers.

The 1983 General Assembly established the 13-member ***Indiana*** Consortium for Computer/High Technology Education. The consortium will guide public school systems in evaluating computer software and hardware capabilities and teacher training on instructional uses of microcomputers. The consortium will help school districts obtain training, hardware and software through low interest loans. The consortium will also establish regional clearinghouses and coordinate teacher training. Indiana is providing $16 million in new funding for this program.

The ***Massachusetts*** State Department of Education began in the summer of 1983 to offer curriculum information through a "Resource Information and Referral" service provided to its regional education centers. Banks of information are now available on writing, reading and curricula for gifted and talented students. By the fall of 1983, information is expected to be available on international studies, foreign languages, instructional technology, mathematics and program evaluation.

In June 1983, the ***New Jersey*** State Department of Education established regional curriculum service units to provide districts in a seven-county region with high-quality, cost-effective curriculum products and services based on district education objectives.

The Center for Learning Technologies has recently been established in ***New York***. The center will provide technical assistance to schools and implement new programs emphasizing computer literacy, interactive technology, program production and inservice training. The state-funded center is located within the New York Department of Education.

The University of ***North Carolina*** is proposing to establish a Network of Mathematics and Science Education Centers. Up to seven centers could be created over a five-year period (1983-88), depending on the need and available resources. Resources would be drawn from three sources: (1) state funds, (2) the instructional resources of each participating institution and (3) other public and private funds. The centers would serve primarily the education needs of middle and high school mathematics teachers by improving preservice programs, conducting continuing education programs and undertaking special studies to improve North Carolina's public schools.

The North Carolina Department of Public Instruction has created eight regional education centers with staff in several curriculum areas including mathematics and computer education. The staff of these centers provide training and technical assistance, among other services, to the schools in the regions.

North Dakota has nine teacher centers which serve the regions of the state. They are administered by a policy board of schools within a district and frequently located within a school or on a college campus. These centers identify and respond to the needs of teachers in the region, make resource people available to schools and disseminate information.

Texas has twenty educational service centers that provide inserve training for mathematics and science teachers. Computer awareness and orientation sessions are available to teachers and administrators.

The Texas Education Agency funds the Texas Education Computer Consortium which includes six educational service centers. The consortium's primary focus is the development of computerized management information systems. Schools in the consortium have access to orientation and training sessions related to computer use.

The ***Utah*** State Office of Education funds five regional service centers that provide a limited amount of inservice training in mathematics, science and computer education.

The nine educational service districts in ***Washington*** organize needed inservice training programs, including sessions in mathematics, science and computer education for teachers and administrators.

West Virginia's eight regional education service agencies provide computer awareness sessions for teachers and administrators. It is anticipated that they will soon offer more computer education programs such as programming and systems analysis.

X. TEACHER TRAINING AND RETRAINING

Alabama governor George C. Wallace's Interim Commission on Science and Mathematics has proposed increases in funding for scholarships and loans for students who agree to teach mathematics and science in Alabama's school after graduation. The loans would be retired at the rate of one year of tuition for each year of teaching.

The ***Alaska*** Office of Educational Technology and Telecommunications also offers inservice training for teachers and administrators through audio or teleconferencing. The Alaska Manual for Educational Computing and other related publications help keep teachers up to date on research software and new instructional applications.

As part of the Education for Economic Renewal program, the ***Arizona*** legislature appropriated $100,000 for a loan program for prospective mathematics and science teachers. The Board of Regents will administer this program, which helps students train as mathematics or science teachers. After students graduate, one year of the loan total will be forgiven for each year they teach in Arizona public schools. Teachers from other disciplines seeking recertification in mathematics or science are also eligible for loans.

The Arizona legislature appropriated $250,000 to the Board of Regents for the creation of mathematics and science institutes at Arizona's three universities. Because the initiative became effective July 1, 1983, the institutes are not expected to be in full operation until summer 1984. The institutes will improve skills of teachers in mathematics and science.

The Arizona Department of Education conducts regional computer awareness workshops to show teachers how to integrate computers into the basic curriculum. Under consideration is K-12 computer-assisted learning programs. The department houses a computer clearinghouse and laboratory. The State Board of Education is considering computer literacy as a requirement for teacher certification.

One recommendation of the Arizona Free Enterprise Task Force is the development of a special certificate to allow nonteachers with expertise in mathematics and science to teach in the public schools. The task force, created in the fall of 1982 through the Department of Education, consisted of approximately 65 people from business, industry and education. The purpose of the task force was to define more clearly the content of a required high school class, "Essentials and Benefits of the Free Enterprise System." Students receive one-half credit for the class. The task force completed its work in May 1983.

In April 1983, ***Arkansas*** legislators approved a program that provides loans to undergraduate students studying to be mathematics or science teachers. A loan can cover up to 50 percent of education expenses, and the state will forgive 20 percent of the loan for every year a graduate teaches in Arkansas.

Fifteen "TEC" Centers (Teacher Education and Computer Centers) were established in ***California*** in 1982 under the California Investment in People program. In cooperation with state universities, the centers offer inservice training for teachers in computer literacy, mathematics and science. SB 813, which became law in July 1983, funds these centers for another year.

California teachers who take university-level summer courses in mathematics, science and other fields receive a stipend from the state through a program administered by school districts.

SB 813, signed by Governor Deukmejian in July 1983, allows schools to hire teacher trainees who have college degrees and passing scores in skill and subject-matter examinations, provided that the trainees have the assistance of a mentor teacher and an individual training plan. The bill also creates the mentor program: experienced teachers who help develop curricula and serve as mentors to beginning teachers receive an additional stipend of $4,000. The plan gives teachers the deciding vote in the selection of mentors and frees districts from the usual collective-bargining procedures. SB 831 also creates a loan-assumption program whereby students who are training or retraining to teach in shortage areas, particularly mathematics and science, receive loans that are forgiven if they subsequently teach those subjects.

SB 813 raises salaries for beginning California teachers by 30 percent over three years, requires people obtaining teaching credentials after September 1, 1985, to complete 150 hours of continuing education in each five-year period thereafter, and sets up a variety of other requirements and programs that will affect all teachers, not only teachers of mathematics, science and computer education. The bill provides $800 million in additional funding for the fiscal year that began July 1, 1983.

In July 1983, the ***Connecticut*** legislature passed SB 948 authorizing state colleges and universities to use unallocated bond funds for a loan forgiveness program for teacher candidates in subject areas with teacher shortages. The funds are distributed using a formula based on the percentage of certified graduates from each of the state's teacher training colleges and universities. Teacher candidates are eligible for loans of up to $5,000 during their junior and senior years of college; loan balances would be reduced by 20% for each year recipients teach in Connecticut.

The Connecticut Project to Increase Mastery of Mathematics (PIMM), in conjunction with the Connecticut State Department of Education, sponsors a summer mathematics institute for 100 teachers in grades 4 through 8. The institute introduces techniques for teaching various topics in mathematics while strengthening knowledge of mathematical content in ways that readily transfer to classroom practice.

The ***Delaware*** state education agency provides inservice training in mathematics, science and computer education.

The Delaware State Council on Computer Education has been conducting many inservice teacher training workshops. More than 2,200 teachers have taken one or more of these workshops. Under consideration is a requirement that all teacher candidates have some coursework in computer education.

Recent legislation in ***Florida*** has established the Teacher Scholarship Loan Program to attract promising students into the teaching profession. Loans are awarded for no more than two years and are not to exceed $4,000 per year. Two years of teaching in Florida's public schools pays back one year of the loan.

Another new program in Florida is the Tuition Reimbursement Program. Certified teachers can receive up to $700 each year for four years while retraining in an area of critical teacher shortage.

The Florida Loan Forgiveness program provides up to $2,000 per year (up to four years) for undergraduate students in Florida's teacher preparation programs, or up to $5,000 per year (up to two years) for graduates of teacher education programs in areas of critical shortages.

Under the new Educational Reform Act, Florida has created the Florida Quality Instruction Incentives Council to advise the State Board of Education and the legislature about the development and use of teacher tests and performance evaluations.

Various ***Georgia*** universities offer summer training for teachers who teach advanced placement courses in science, mathematics and other subjects; some teachers will train at a technology center at a Macon vocational-technical school.

The State Department of Education in Georgia has received $135,000 in state funds for FY 84 for loans to graduate and undergraduate students in mathematics and science education. Maximum loans are $1,500 per full-time academic year. For each year the receipient of a loan teaches mathematics or science in a geographically underserved part of Georgia, up to $1,500 of the loan is forgiven.

The ***Hawaii*** Office of Public Instruction provides four special resource centers to serve its local education agencies. These include science resource centers, mathematics centers, computer education centers and a teachers resource center.

In Hawaii, the Science Institute and the Mathematics Institute provide workshops during the summer and courses during the school year for both students and teachers. This year the Mathematics Institute is providing teacher training programs; the Science Institute is providing advanced courses and innovative programs for gifted students.

One initiative of the Governor's Education for Employment Program in ***Illinois*** will create seven sites for intensive inservice training of 200-250 vocational education teachers in applied mathematics and science. Each site will receive $80,000 the first year. Curricula will include computer education, technology and physical science courses with business and industrial applications. Selection criteria for teachers are currently being finalized and will likely attract teachers from secondary schools and community colleges. The inservice appropriation is $150,000; technical assistance programs will receive another $150,000; and the remaining $250,000 will be used for equipment purchases.

SB 570, sent to the Governor of Illinois on July 22, 1983, authorizes the Illinois State Board of Education to award annual scholarships to certified teachers who wish to take additional courses and teach at the secondary level. The scholarships would provide for tuition at public or private colleges.

The Illinois legislature appropriated $1 million to develop computer consortia for training school personnel in computer education. Eighteen consortia were funded through Chapter 2 funds ($350,000) so that every Illinois school district belongs to one consortium. The consortia will conduct inservice training and staff development programs, develop and maintain software libraries and acquire equipment for loan and demonstration. The program is appropriated through general revenue funds and began June 1983.

HR 329 directs the Illinois Board of Higher Education and the State Board of Education to study and make recommendations about the use of nonteacher experts in mathematics and science in the public schools. The experts would serve as adjunct faculty to certified teachers. Recommendations are to be reported by March 1984.

A bill to establish a Loan Repayment Assistance Fund was enacted in 1983 to help repay the college loans of students who remain in ***Indiana*** to become teachers in mathematics, science or other shortage areas. The Indiana State Student Assistance program will administer the program beginning July 1983. The program has been funded at $50,000 per year for the next two years. Students can borrow up to $10,000; up to $2,000 per year of a loan can be forgiven as long as the recipient remains in the Indiana public school system and teaches mathematics or science. $100,000 has been appropriated for 1984-85.

The Teacher Retraining Grant program in Indiana provides a grant of $1,000 each year for up to two years for licensed teachers who wish to retrain in mathematics and science.

Through ***Iowa's*** HF 532, students training to be teachers of mathematics or science are eligible for loans, $1,000 of which will be forgiven for each year they teach mathematics and science courses in Iowa schools (up to $6,000). Certified teachers who go back to school to get recertified in mathematics or science are eligible for loans of up to $1,500; if they then teach mathematics or science for one year in Iowa schools, one-half of the loan is forgiven; if they teach two years, the entire loan is forgiven. The same bill provides $40,000 for the fiscal year beginning July 1983 and $140,000 for fiscal years thereafter for inservice programs to improve the teaching of mathematics and science.

Kentucky has instituted a mathematics and science scholarship program to encourage more education students to become certified or recertified in those areas of shortage. The program allows $2,500 of the loan to be forgiven for each year teachers teach mathematics or science within the state.

The Kentucky Department of Education has provided tuition for one person from each school district to participate in a three hour graduate course on computers conducted at the eight state universities this summer. Also, teacher training was provided to all teachers in the state while students competed in the Kentucky Computer Problem Solving Contest in April 1983.

To date, the Kentucky Department of Education has sponsored two awareness conferences and four indepth computer conferences for approximately 1,200 participants. Participants included classroom teachers, administrators, school board members and college personnel.

The ***Louisiana*** legislature recently passed a forgivable college loan program to encourage students into mathematics and science teaching. Under this bill, students could qualify for loans up to $9,000 over three years, and for each year of teaching in the state, one-fifth of the loan would be repaid. Governor Treen signed the bill but implementation is pending because of similar legislation before the U.S. Congress. To further advance teachers' ability in mathematics, science and computer education, Louisiana exempts tuition for advanced college work in certified areas. Extra pay incentives are granted to teachers for experience and advanced study under the Professional Improvement Points

(PIP) program. The Department of Education offers inservice computer education courses. In addition, colleges of education are developing major and minor fields in computer-related courses.

The University of Sothern ***Maine*** has initiated a program this year to attract people from other professions into teaching. The six-month program seeks individuals who are interested in a mid-career change and already have a bachelor's degree. Fifteen students have been selected to participate in a six-week summer session, which will be followed by eight weeks of independent study to prepare for internships in the Portland school system. Each candidate will be supervised by a master teacher and faculty advisor. The experimental program will be evaluated to determine its future.

Michigan now has a group who will recommend alternatives to upgrade certified teachers' skills in mathematics and science. The Michigan State Department of Education has formed a Mathematics and Science Committee that will make recommendations for upgrading the skills of certified mathematics and science teachers. The committee is composed of representatives from business and industry, colleges and universities, teachers and administrators. The committee will report the findings sometime this fall.

In May 1983, the ***Minnesota*** legislature appropriated $500,000 for inservice training of school district staff. The first year will be devoted to training elementary and secondary staff in mathematics, science and social sciences. The state commissioner will recommend to the legislature subject areas for which inservice training is needed in subsequent years. The training programs will be designed to include activities requiring active participant involvement. The appropriation was made under the Technology and Educational Improvement Act.

The Minnesota legislature appropriated $936,000 for inservice training in the use of technology under the Minnesota Education Technology Act. Technology includes, but is not limited to, computers, telecommunications, cable vision, interactive video, film, low-power television, and satellite and microwave communications. Each school district with an approved technology utilization plan may apply for state aid to provide inservice training for elementary and secondary public school staff. By June 30, 1985 the Department of Education must provide supplemental regional or statewide inservice training for local districts in the use of technology.

Loans will be available in ***Mississippi*** to students enrolled in teacher education programs who plan to teach mathematics or science. Teachers certified in other fields may apply for loans up to $1,000 per year to go back to college during the summer for retraining in mathematics or science. To receive a loan, teachers must agree to teach at least one semester in high school for each semester they accept the loan. Teachers are expected to complete their retraining within three years. $900,000 is available for this program.

Another Mississippi loan program approved by the legislature is designed to attract college students into mathematics or science teaching. College juniors and seniors can receive up to $3,000 in loans per year, if they agree to teach one year in Mississippi for each year they receive the loan.

The Education Reform Act requires the Mississippi Department of Education to conduct a study by July 1, 1984, to determine the extent to which teachers are teaching out of their fields of certification, the conditions that promote such practice and appropriate remedies.

Southwest ***Missouri*** State University and Northeast Missouri State University have established summer mathematics institutes to provide 11 credit hours to 30 elementary school teachers who retrain to teach mathematics in junior high. Tuiton is $450, $350 of which is paid by the school district and $100 of which comes from the State Department of Education. The University of Missouri and Marysville College provide inservice training to limited numbers of mathematics and science teachers.

The ***Montana*** Council of Teachers of Mathematics (MCTM) takes a very active role in mathematics education throughout the state. The council oversees, organizes and directs the applications and use of National Science Foundation grants; provides inservice teacher workshops; and attracts over 2,000 teachers to its annual state meeting.

This year the ***Nebraska*** State legislature passed a bill to provide loans at 5 percent interest to mathematics and science education majors in state colleges and universities and also to certified teachers studying mathematics or science education. There are also workshops in computer literacy for education department staff members and for some school districts.

In ***New Jersey***, more rigorous teacher training standards have been adopted by the State Board of Education and higher education. Prospective teachers are required to have a 2.5 GPA or better to enter and maintain status in a teacher training program. More stringent requirements for field-based preservice experience have been mandated. Further revisions are currently being considered.

The ***New York*** Department of Education conducts an inservice computer literacy course for K-12 teachers. The training consists of an introduction to computers and the opportunity for hand-on experience.

The New York Board of Regents and the state education department are proposing legislative initiatives to promote preservice and inservice training for mathematics and science teachers. Proposals include undergraduate scholarships and graduate fellowships for prospective teachers of mathematics and science, funding for inservice training for public school teachers and establishing consultantships in elementary and secondary mathematics and science.

North Carolina provides retraining, loans, scholarships, fellowships, extended contracts and provisional emergency certificates for teachers in mathematics and science. The state is studying the development needs of teachers and teacher supply and demand. A $1 million summer program recently went into effect under which mathematics and science teachers instruct inservice teachers during six-week workshops. Certified mathematics or science teachers are also eligible for scholarships to upgrade their training under the program. Three hundred mathematics and science teachers have been offered six weeks of summer employment in the public schools. The Mary Reynolds Babcock

Visiting Instructor Program allows selected high school teachers to teach a reduced load at the North Carolina School of Science and Mathematics.

To ensure appropriate certification of new teachers in North Carolina, the State Board of Education is creating a Quality Assistance Program (QAP). During the first two years of employment, new teachers will work under the close supervision of local school people and people from teacher training institutions. New teachers will receive permanent certification after two years of successful teaching. Considerable inservice training is part of the QAP program.

The ***North Dakota*** Department of Public Instruction is cooperating with the North Dakota State University to conduct a teacher training program in mathematics. It is designed to lessen the shortage of qualified high school mathematics teachers by allowing interested teachers to complete a 12-week summer course for four credits. When participants complete a total of 19 credits selected from six fields of mathematics education, they can be certified to teach mathematics.

During the fall of 1982, the ***Ohio*** Department of Education conducted a study on teacher supply and demand and found neither a surplus nor a shortage. The department then published brochures for prospective teachers suggesting areas that are overcrowded and those in which employment prospects are most likely.

SB 198 appropriates $300,000 to encourage students to enroll in mathematics and science teaching programs in ***Pennsylvania*** and to encourage graduates certified in mathematics and science to enter the teaching profession. The bill amends the Pennsylvania Higher Education Assistance Agency Act by granting $100,000 in forgivable loans to students who teach mathematics or science in Pennsylvania's public schools. The balance of the appropriation is earmarked for retraining science and mathematics teachers and for developing public and private partnerships to improve instruction. Governor Thornburgh signed the bill in July 1983.

The ***South Carolina*** legislature has funded programs that will begin in the 1983-84 school year which allow elementary and secondary teachers to receive credit for inservice training in science, mathematics and computer education. Programs provide up to six credits of science and mathematics and special training in computer literacy, curricula applications, and the teaching of programming.

The South Carolina Board of Education and the Department of Education have encouraged the investigation of additional activities to ease the shortage of mathematics and science teachers. Three ideas have received attention: (1) the recruitment and training of adult professionals from business and industry to work part-time in schools; (2) the creation of a "teacher corps," a team to teach mathematics, science and other subjects in high-need counties; and (3) retraining of teachers who wish to switch fields. The first idea appears to have received the greatest attention, as evidenced by the fact that four teacher preparation institutions are expected to have adult apprenticeship training programs for special education in operation by the beginning of the 1983-84 school year.

These four institutions have been working with the Board of Regents to develop a new training model that allows professionals in a variety of fields, including those where shortages exist, to accelerate their training for teaching. Under this new training program and restyled permit standards, adults holding baccalaureate degrees who have professional experience in a particular field would have the option of entering teaching without completing the traditional teachers' college program. One of the stumbling blocks to development of a similar pilot program in mathematics has been the availability of funding.

The South Carolina Department of Education is sponsoring summer institutes for retraining teachers of mathematics and science and training other teachers in these disciplines. South Carolina does not yet face shortages of mathematics and science teachers, but the department anticipates that enrollment in these disciplines will rise markedly. Thus, the department is especially concerned to encourage teachers in other disciplines to work toward certification in mathematics and science. Certification renewal now requires six credit hours of inservice training in the subject(s) for which a teacher is certified; the department proposal would allow all six hours to be taken in mathematics and science.

South Dakota has state board requirements for certification of teachers who teach computer courses in local districts. These teachers will have to complete a minimum of eight hours of college credits in computer courses. Also, state conferences and regional workshops provide sessions on computers in education for local staff development. Regional inservice days are held to upgrade teachers' knowledge of mathematics and science. South Dakota is discussing special loan programs for mathematics and science teachers.

The ***Tennessee*** Department of Education completed in 1983 a teachers' guide for computer literacy in grades 7 and 8. As part of the Computer Skills Next program, the state is implementing a two-year plan to train teachers in the new computer literacy curriculum. The Microcomputer Advisory Committee has recommended training 60 inservice experts, who will then train 4,300 7th and 8th grade teachers. Seven hundred teachers will receive additional training as computer literacy teachers. By 1985, nearly all 7th and 8th grade teachers will be computer literate.

SB 50 passed in the 1981 ***Texas*** legislative session, mandated two kinds of competency tests for teachers, one a test of basic skills upon entry into a college teaching program and the other a test in the major subject area upon completion of the program. These tests are now being administered on a pilot basis throughout the state.

A bill passed by the Texas Legislature this year provides funds to develop innovative approaches to training mathematics and science teachers.

The severe shortage of mathematics and science teachers in Texas necessitated the issuance of more than 500 emergency teaching permits in these subjects last year. Lawmakers have been studying a variety of proposals to address the shortages. Among the bills considered were the following: (1) a bill to fund a loan forgiveness program for teachers who switched to mathematics and science from other fields; (2) a bill to provide low interest loans to students in mathematics and science education; (3) a bill that would allow districts to hire mathematics and science teachers from industry if no certified applicants were available.

A bill that would allow districts in Texas to run summer programs for retraining mathematics and science teachers passed both houses of the legislature, but the funding provision in the bill has been removed. Lawmakers did pass and fund a bill to develop innovative approaches for training mathematics and science teachers.

The ***Utah*** Office of Education and the Utah Council of Teachers of Mathematics are sponsoring a two-week workshop in mathematics this summer. The program is designed to provide intensive training to teachers who have little or no college-level mathematics. Superintendents nominated teachers who will be teaching mathematics, often for the first time, this fall. (In Utah, teachers are not certified by subject area. Once they receive a secondary-level certification, they can be placed wherever they are needed.)

The University of Utah has adopted a program to award $1,500 scholarships to students who are pursuing secondary-level certification in mathematics, science or a foreign language and who plan to teach in Utah.

It is anticipated that the Microcomputer Information Laboratory currently being developed in Utah will train teachers and administrators.

The ***Vermont*** legislature passed a bill in May to establish a $50,000 loan program for teacher education candidates in science, mathematics or computer education. The program will begin this fall and students may apply for up to $2,000 per year. A portion of the loan will be forgiven for each year taught in the Vermont public schools.

Vermont has recently increased funding for the Vermont Student Assistance Loan program (VSAL) by 14 percent. In May 1983, the Governor signed a loan-forgiveness bill. Beginning in the fall of 1983, Vermont students majoring in science, mathematics and computer science education can receive state loans of up to $2,000 annually. These loans will be forgiven at a rate not to exceed 25 percent of the principal and interest for each year the recipient teaches in Vermont public schools.

The Vermont Department of Education organized a pilot workshop in the summer of 1983 to improve the teaching skills of science teachers, including elementary teachers preparing for the new early-childhood program that begins in the fall of 1983.

The Vermont Department of Education is also setting up a teacher placement service to help districts locate teachers to fill vacancies. The department will advertise openings in Vermont and nearby states.

While the Vermont Department of Education has not mandated a computer education curriculum, it recently issued regulations that require teacher preparatory programs to train teacher candidates in uses of computers.

A scholarship program has been established in ***Virginia*** to help teachers add science and mathematics to their certifications and to attract new teachers to these fields. The Department of Education has also proposed a loan forgiveness program in its 1984-86 budget, offering up to $1,000 for teacher candidates in mathematics and science.

This year, as part of the Governor's budget, the ***Washington*** legislature provided funds to the Office of the Superintendent for Public Instruction for inservice training in mathematics, science and computer education. A total of $244,000 will be available over the next two years to local education agencies and educational service districts that respond to requests for proposals issued by the state.

Washington's High Technology Education and Training Act, also passed this year, includes funding for inservice training. Regional computer demonstration centers, also to be established with funding from this Act, will serve as computer technology training sites for teachers and administrators.

In other legislation, Washington lawmakers this year authorized forgivable loans for students who have declared mathematics or science education as their major, who meet state requirements for need and who maintain a 3.0 grade point average. The loan program, which is for undergraduate students and teachers returning for an additional teaching endorsement in mathematics or science education, is being administered by the Council for Post-Secondary Education. A total of $500,000 will be available over the next two years for these loans. Each student who meets the eligibility criteria can receive a maximum of $2,500 per year for each academic year. Ten percent of the loan plus interest is deducted for each year a teacher teaches in a public middle, junior high or high school in the state. If a teacher teaches for 10 years, the loan is entirely forgiven. Funding for the loan forgiveness program will be available by the fall of 1983.

All four sections of Policy 5100 (Assuring the Quality of Learning in ***West Virginia*** Schools: Plan for Professional Development of Educational Personnel), including preservice testing of teachers by September of 1985, are the focus of much planning and discussion in the state. Adopted by the State Board of Education in April 1982, Policy 5100 is being phased in to redefine objectives in basic skills, general education, content areas of specialization and professional education. Task forces and study groups examining each of the four areas are now submitting their recommendations to the State Board of Education and State Board of Regents.

To improve mathematics and science teaching in ***Wisconsin*** and to enlarge the supply of mathematics and science teachers, the State Superintendent is proposing the following initiatives that will be considered by the legislature in October: (1) grants of $4,000 to present mathematics and science teachers to return to school for one year; (2) grants of $8,000 to secondary school teachers to retrain in mathematics or science; (3) scholarships of $2,500 to undergraduates majoring in science or mathematics; (4) master teacher positions to staff teaching centers; and (5) grants to vocational teachers to improve their skills in mathematics and science.

Effective July 1, 1983, the ***Wyoming*** State Superintendent of Public Instruction will award scholarships to secondary school teachers seeking to improve their skills or prepare themselves to teach in the fields of computer science, telecommunications, higher mathematics, foreign languages and science (particularly chemistry and physics). Each scholarship of $250 is to be supplemented by an equal amount from the school district where the teacher is employed. An amount of $2,500 will be available for scholarships. The act expires June 30, 1986.

APPENDIX A

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ECS 50-State Survey of Initiatives in Science, Mathematics and Computer Education

August 1983

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APPENDIX B

Additional ECS 50-State Surveys

The Education Commission of the States has completed 50-State surveys on teacher policies and school improvement programs. These are:

Survey of State Teacher Policies contains state-by-state teacher information on teacher training, certification, and staff development; on incentives to attract new teachers or to reward exemplary teaching; and on programs to retrain teachers or to deal with statewide teacher shortages.

State Programs of School Improvement updates the 1982 ECS 50 state survey of school improvement activities sponsored by the states, including state developed curricula or curriculum guidelines, changes in accreditation standards, "effective schools" programs, local building programs, and new strategies of student testing.

These surveys may be obtained from the Education Commission of the States, 1860 Lincoln St., Suite 300, Denver, CO 80295.

8

MAGNET SCHOOLS*

Denis P. Doyle and Marsha Levine, ***The American Enterprise Institute***

ABSTRACT

Although there is a long history of highly selective magnet schools in the United States, their modern incarnation is relatively new and highly successful. This essay begins with a description of the history and changes in magnet schools, beginning with those schools created to serve the needs of a small, intellectual elite to today's magnets with the twin focus of increasing school integration and improving education quality.

The essay goes on to describe the schools as we know them today based on the most recent research findings. Today's magnets include district-wide open-enrollment institutions, thematically organized, which are largely non-selective—that is, as that term is ordinarily understood. They do not simply cream "gifted" students, they attract students who are motivated and interested in the focused program the magnet offers.

On balance, modern magnet schools achieve their objectives with a high degree of success; they increase the degree of racial integration and improve the racial climate. Indeed, the level of improvement is frequently so high that magnet schools may turn their attention to matters of pedagogy and instruction. In addition, morale is higher, discipline problems less, and student outcomes higher. The evidence for these findings is limited but powerful. The major work in the field is at present underway, but portions of it are now available. This paper summarizes and highlights the information and findings currently available. The final report should be released in completed form by the fall. (The research is being carried forward by James Lowry and Associates and their subcontractor, the Abt Corporation, under the terms of a Department of Education contract.)

On the strength of these findings, we conclude that magnet schools are an important strategy for school reform and suggest two roles for the federal government. First, continuing research and analysis should be supported to increase our knowledge base about long-term effects of magnet schools. Second, we now know enough about magnet schools to build a major and lasting reform strategy around them. We propose combining the educational effectiveness of magnet schools with the land grant college model, a proven strategy for innovation, education, and local capacity building, initiated through the leadership of the federal government.

Specifically, we propose that the federal government build on its historic record of accomplishment as a facilitator of a multi-purpose enterprise for

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**A Paper Commissioned by the Pfizer Corporation* research, education, innovation, and dissemination; i.e., the land grant college system, and initiate a similar program for magnet schools across the nation. It is a strategy of excellence in education which rests on the sound educational premises of student and teacher motivation combined with a decentralized system of implementation which encourages all levels of government, the private sector, and postsecondary institutions each to play appropriate roles in contributing to education improvement.

We conclude by proposing that the federal government support a large-scale magnet school demonstration program of three magnets for each standard metropolitan statistical area, and several additional magnets per state based on population. This would more than double the existing number of magnets (from little more than 1000 to 2000-plus) and would lay the foundation for long-term, incremental change.

INTRODUCTION

As their name implies, "magnet" schools are an education lode stone, designed to attract students (and faculty) on the basis of their special qualities. The key characteristics that define magnet schools are voluntary enrollment and thematic organization: magnet schools are found in the public and private sector, at the elementary and secondary level, they are academic and non-academic, selective and non-selective. Typically, they are organized by pedagogical theme, science and math, music and art, or the humanities, for example. Their diversity is itself an identifying factor. These characteristics—voluntary enrollment and diversity—run counter to the major forces which have shaped public schooling. They are, however, the exception that proves the rule.[1]

For generations two major forces shaped America's public schools: first was place of residence. For generations, it determined where one went to school. Indeed, in American education, geography was destiny. Second was the continuing search for "one best system" to educate all children. These interlocking ideas produced a common school culture in which most public schools were surprisingly similar.

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[1] By almost any definition except "tuition," many private schools are magnet schools. Although Catholic and other religious elementary schools frequently are organized by neighborhood, most private high schools serve regions. The oldest and most prestiguous—St. Paul's and Exeter for example—serve the nation. Closer to home, most Catholic order schools serve metropolitan regions, and frequently their student bodies include large numbers of non-Catholics. Most non-Catholic day and boarding schools serve regions as well.

Although private schools fall outside the scope of this essay, it is clear that they represent a rich analytic vein for the researcher who is interested in questions of choice and diversity, particularly pedagogical and curricular diversity.

For a more complete analysis of private schools and the social and pedagogical role they play see Denis P. Doyle, "A Din of Inequity: Private School Reconsidered". *Teachers College Record*, Vol 82, No. 4 (Summer 1981): 66–674.

Student characteristics—high motivation, intellectual or artistic interests and capabilities—have had little bearing on the kind of school a child attended. The underlying reason for neighborhood assignment, of course, was not pedagogical; it emerged organically for reasons of administrative convenience. As neighborhoods appeared, schools sprang up to serve them; what began as a simple administrative expedient has become an issue which fuels heated debate, but it is clear in terms of the historical record that neighborhood assignment had no pedagogical theory to dignify it.

American schools—public and private—exhibit nearly identical organizational and pedagogical arrangements because they spring from a common culture of schooling. They are the product of a shared vision of how schooling should be organized and operated. The principal difference between schools lies on a qualitative scale: a fast-track academic private school expects more of students, but is still organized in much the same way as its public analogue. Both have days divided into periods in which teachers lecture and students respond; both assign letter grades; both group children by age rather than by demonstrated or intrinsic ability; both offer courses of study for fixed time periods, usually semesters, rather than the time needed to master the material. This common approach to the common school is the product of a conviction that "one best system" could be designed.

Captured best in David Tyack's fine book of the same title, it reflects America's "can do," pragmatic spirit.[2] Following the lead of the scientific management revolution, American schools began to look like neat little factories, with students the product, teachers the workers, administrators the management, the Superintendent the CEO, and the School Committee the board of trustees. And as the production line worked for business, it worked for the school. To only slightly oversimplify, it was because of this that most American schools began to look each like the other. As a consequence, it made little difference in which school a child enrolled: they were all very nearly the same. What had begun as an accident of geography and administrative convenience, then, became a virtue: it was "good" for children to attend neighborhood schools.

Its logical culmination was James Bryant Conant's comprehensive high school, the subject of his important work, *The American High School Today,* published in 1959.[3] American education accepted Conant's proposals with a vengeance, and the pressures for uniformity in schooling increased.

It is precisely the limitations of the comprehensive high school, however, that ushered in the modern wave of magnet schools.

The limitations of the comprehensive neighborhood high school are several. Frequently, they reflect the residential patterns of racial isolation characteristic of much of the nation's urban areas, and the schools were themselves predominantly of one race. From a pedagogical standpoint, the broad curriculum of the comprehensive high schools lacked the depth of more sharply focused schools. The fact that assignment was "involuntary" tended to undermine the morale of teachers and taught.

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[2] David Tyack, *The One Best System: A History of American Urban Education*, Harvard University Press, Cambridge Mass., 1974.

[3] James B. Conant *The American High School Today*, McGraw-Hill, New York, 1963.

Conceptually, it was no great leap to magnet schools: organized around an academic or vocational theme, stressing voluntary participation, magnet schools held the promise of racial integration, higher morale, more focused study, and higher student outcomes, which is to say, higher performance as measured by tests. In particular, magnet schools looked like a powerful strategy to encourage voluntary desegregation.

EARLY MAGNET SCHOOLS

Although neighborhood schools have been the norm in American education for decades, there is a modest but distinctive history of non-neighborhood schools, principally fast-tract academic or specialized vocational schools that draw on the population of the whole school district. Not known as magnet schools when they were created, they nevertheless fit the definition. The most well-known are a sort of honor roll of American education: first and oldest is Boston Latin, founded in 1635, a year before Harvard University. In addition are schools known to educators throughout the country: Lowell in San Francisco, Central High in Philadelphia, Bronx Science in New York, Aviation in Queens, Lane Tech in Chicago, Performing Arts in Manhattan.[4]

Indeed, magnet schools represent a striking break with the tradition of neighborhood assignment. Their selectivity, diversity and voluntarism run at cross purposes to comprehensive school and neighborhood attendance orthodoxy. Yet the selective magnet school model has managed to survive and the concept has been developed into a contemporary variation with the dual purposes of quality education and integration. In both their original and hybrid forms, they are the subject of intense interest.

But their history has been checkered. Frequently accused of elitism, selective magnet schools have on occasion had to fight for their lives. Like flies in amber, New York City's three selective academic high schools, for example, found it necessary to get special legislation enacted to preserve themselves in statute. The legislation is no small matter: it does not just solemnize their existence but protects them from bureaucratic intervention and even dissolution.

Indeed, not all selective schools have been so fortunate. A bleak fate befell Dunbar High School in Washington, D.C. in the mid-1950s.[5] Dunbar was widely viewed as the nation's premier black public high school. Founded in

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[4] The material on New York's selective schools is based on site visits by one of the co-authors. Denis Doyle, in May 1983, interviews with the principals and senior staff, and a random selection of interviews with teachers and students, and printed material prepared by the schools themselves.

[5] Fred Hechinger, "About Education: Debate on the Role of Elite Schools", *New York Times*, February 5, 1982.

1870, Dunbar is described by Fred Hechinger of the *New York Times* as "the first public high school for blacks in the U.S. operating on the principle of selectivity and quality. The quality of its students and faculty was matched by few contemporary public schools."[6]

In spite of the limitations imposed on it by a society that employed the oxymoron "separate but equal," Dunbar flourished. It was an island of excellence, high standards, and a source of pride to generations of graduates, teachers, and friends. It was a magnet school of the day, drawing able black children from all over the city; and a number of children who were not D.C. residents in the full, legal sense, moved in with friends or relatives to attend Dunbar.

Hechinger notes that "among Dunbar's illustrious alumni were Benjamin O. Davis, the first black general in the United States Army; Dr. Charles Drew, who devised the method of storing blood plasma and set up the first blood bank for the American Red Cross; and former Housing Secretary Robert Weaver, the first black cabinet official."[7] In a great historic irony, the D.C. School Board converted Dunbar into a neighborhood high school as a response to *Brown v. Board of Education*. This spelled the end of fast-track public education in Washington, D.C. for both black and white students, and it has only been in the past few years that magnet schools have reappeared in Washington, albeit in attenuated form.

ELITISM

The charge of elitism has plagued selective schools, and by extension magnet schools generally. Basically, the refrain is sung on two notes: the first is that separation of children by ability is intrinsically wrong, it is undemocratic. The second is a more conventional and more frequently heard instrumental argument: schools that enroll the brightest children deny them to the rest of the system, plunging the remaining schools into a morass of mediocrity. There is, of course, virtually no empirical work in this field for the twin reasons that it is difficult to do methodologically, and no funding agency has thought to do it. But there is some theoretical work.

The most powerful is a short, elegant book by Albert O. Hirschman, titled *Exit, Voice and Loyalty*.[8] He argues that the quality-conscious consumer will not tolerate the inferior product of public monopolies. Although Hirschman's point of departure is the state-owned railroads of a West African country, he extends the analogy to public and private schools. Just as the quality-conscious parent cannot tolerate low quality public schools, neither can the public monopoly tolerate the continuing complaints of a small but vocal group that cares about quality. Both make life miserable for the other. As a consequence, each side reaches an uneasy truce in which the quality-conscious consumer is permitted to take advantage of a high-quality option. In the West African case, the alternative is privately owned trucks which compete directly with the state railroad monopoly. Customers like the quality—on-time service—and the state monopoly is greatly relieved to be done with the complaints of the quality-conscious: for this reason they tolerate the private competition.

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[6] Hechinger, *Ibid*.

[7] Hechinger, *Ibid*.

[8] Albert O. Hirschman, *Exit, Voice and Loyalty: Response to Decline in Firms, Organizations and States*, Harvard University Press, Cambridge, Mass., 1970.

In the case of education, parents who care enough find an alternate provider, private schools that charge fees, "better" suburban schools, or public magnet schools.

This theory provides a powerful explanation for the existence of private schools generally and the continued existence of selective public schools in a few major cities: New York, Boston, Philadelphia, San Francisco. A sort of grudging *modus vivendi* emerges, because the school system realizes that the selective schools serve an important but limited function, satisfying the small number of vocal, quality-conscious consumers.

The political tension revealed in this situation is tangible; it goes to the heart of a long and honorable American tradition of emphasis on equality and antipathy toward privilege. But it also reflects a fundamental view of education which is seriously flawed. And that is the idea that for every winner there is a loser, for every good school a bad one. It is the logical if wrongheaded extension of the idea that there is "one best system" of education; it is deeply ingrained in American life. If there is only "one best system" to educate children, then the assumed bell-shaped curve of intellectual ability means that when the brightest children are "creamed" and put in a selective school, the rest of the system suffers. Although the argument is not supported by evidence, its "face validity" is strong and deserves a response.

First, it is built on erroneous assumptions about what makes a good school. As we know from the private market, which includes an array as diverse as Quaker schools and military academies, Waldorf schools and Jesuit schools, international baccalaureate schools and A.S. Neil Summerhill schools, there is no one best system of education.

That this is so is revealed with equally great power in New York City's selective public schools. The three academic schools already mentioned—Stuyvesant, Bronx Science, and Brooklyn Tech—compete with each other and with Music and Art, Performing Arts, and Aviation, which are equally selective. Together they represent an extraordinary range of diversity and choice. (They also compete with private schools, head to head. It is one of the few "markets" of its kind in America.)

As compared to each other, the differences they represent are not differences in intellectual ability but different pedagogical interests, a different way of interacting with the world.

These schools also reveal that good education for one student and one teacher may vary greatly from what other students and teachers need. Indeed, does anyone's experience suggest otherwise?

To treat the concept of magnet schools as synonymous with selective schools, however, is both politically and pedagogically limiting. Politically limiting because it raises the question of elitism unnecessarily, and pedagogically limiting because it makes too much of selectivity. Indeed, except in extreme cases, rational selectivity is difficult to implement. Take the case of New York's three academically selective high schools. As many as fifteen thousand children take the entry examinations each year for approximately two thousand, five hundred openings (nearly one million children attend New York City public schools).

Only the highest-scoring students are permitted to attend the three schools: but what of the next two thousand, five hundred, and the next? The few points on entry examinations that separate the top from the runners-up cannot really measure difference in intellectual ability. The obvious solution is to add additional special schools so the runners up will have a choice as well. And this is precisely what is beginning to happen.

THE NEW WORLD GRAMMAR SCHOOL

The selective schools described so far grew organically from the British grammar school model, a program of fast-track, college preparatory education. They are elite schools for elite students. Indeed, unlike the American comprehensive school, the grammar school is characteristic of education throughout the world. Each of the advanced industrialized nations—free and totalitarian—as well as almost all less developed countries employ elite models of education. In France, China, Russia, and Uganda, entry to each higher level of schooling is secured by passage of progressively more rigorous examinations. These elite systems, however, are not solely the product of a national passion for high quality. To the contrary, they reflect a hard-headed decision to sharply ration education by objective means. Because only a limited number of seats in first rate schools are available, only the highest scorers are permitted to enroll. Recent student riots in France occurred precisely because the government decided to reduce the number of seats available and to ration them by even more rigorous examinations.

The American genius has been to create genuine mass education in which access is assured to all, across the board, in ways that leave most foreign visitors amazed. (It is equally amazing to them that we have any education standards at all, one might add.) For all the problems with American education, the accomplishment of mass education is one of which the country should be justifiably proud.

The dichotomy between the American and foreign models has led to an unfortunate view of education as a "binary" enterprise, either elitist or egalitarian. At one end of the scale is the English grammar school, at the other the comprehensive American high school. One is open to the best and brightest, the other open to all. One is aristocratic the other democratic.

Interestingly, at the level of higher education there exists a hybrid, and it is an American invention. It combines high standards with broad, open access. In its first incarnation it was the land grant college. Open to all, many were unable to meet the demands placed upon them after they enrolled. The personal and institutional price was a high rate of attrition. Today, the most distinguished system of higher education in the world—California's—is self-consciously designed to simultaneously satisfy equity and quality interests. Any Californian with a high school diploma (or who is age 18) may enroll in the third tier of the state's three-tiered system, the community colleges. Better prepared students may go directly to the State University system; and the very best students may enroll in the University of California system. Movement among segments is encouraged and frequently occurs.

CONTEMPORARY MAGNET SCHOOLS

Magnet schools, then, can be designed to retain open access as they build on the crucial intangible of education motivation. They can be built around a philosophy of inclusion rather than exclusion, open to any student who cares to attend. In such a setting, the likelihood of school success is substantial. No longer unwilling victims of schooling, in magnet schools students become willing and eager participants.

Magnet schools offer other possibilities as well. Choice is a virtue, not only because of different learning styles, but because different people have different things to learn. Thus, music and art magnets, vocational magnets, humanities magnets, as well as science and math magnets make pedagogical as well as social sense.

As well, magnets exhibit an ambience or ethos which has a powerful effect on personal behavior. Just as additional homework may be expected, so may standards of dress and behavior. A magnet school may require community service as a condition of graduation where such requirements would be intrusive and onerous if expected of all students in a given school district.

Of equal importance, magnet schools offer a setting in which teacher-generated reform initiatives may take place. Imagine, for a moment, the implementaton of the Carnegie-sponsored reform study being directed by Ted Sizer, former Dean of the Harvard Graduate School of Education. Reported in the June *Phi Delta Kappan*, Sizer proposes, among other things, an end to age grouping of students and the wholesale adoption of ability/achievement grouping, in which students would assemble on the basis of what they know, not how old they are.[9]

As interesting as Sizer's idea is, how might it be implemented? Should a state board of education impose it by fiat? Should the federal government support demonstration projects? Should a court order it (or forbid it)? Clearly, the most intelligent and humane way to implement such an idea is for a caring and interested community to take it upon itself to try it. This is precisely the kind of opportunity magnet schools present. Composed of a community of scholars, they should be encouraged to pursue their lights as they see them.

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[9] Theodore Sizer, "High School Reform: The Need for Engineering", *The Phi Delta Kappan, June 1983*.

The reasons for creating magnet schools vary greatly as well; in many communities they have been designed to facilitate racial integration, in some to provide special instruction for gifted and talented students, in others to offer vocational training in a cost-effective manner. As well, they reflect the special resources of their host communities. New York's Performing Arts school is on 46th Street near 6th Avenue, hard by the theater district. Its new forty-five million dollar campus, which opens in September 1984, will combine Music and Art with Performing Arts in one building, kitty-corner from Juilliard, across from the New York Library of Music, behind Lincoln Center. Similarly, Houston's School of Engineering Professions reflects Houston's stake in a high-tech future.

The wide variety of magnet schools now in operation is revealed in selected, thumbnail sketches:

- Aviation High in Queens prepares students for technical careers in aviation. Its best students simultaneously earn Regents diplomas (New York State's coveted academic diploma) and FAA certification in airframe and/or power plant maintenance. Graduates go on to employment, the military, and higher education.

- The Philadelphia High School for International Affairs began in 1981 to "continue . . . voluntary desegregation" through the introduction of magnet schools. Jointly sponsored by the World Affairs Council of Philadelphia and the Philadelphia School District, it is racially balanced, offers a full curriculum including four years of the same foreign language and a concentration in both basic business skills and global studies.

- Baylor College of Medicine and the Houston Independent School District jointly sponsor the High School for the Health Professions. Eleven years old, approximately ninety percent of its graduates go on to college and pursue a health-related field. Half the graduates are minority group members.

Even a cursory review of magnet schools reveals differences as important as the similarity the nomenclature "magnet" implies: they are different schools for different purposes. They serve different students and reflect different community resources and interests.

Although the philosophy and purposes of magnet schools can be enumerated, much of what we know about them is anecdotal and idiosyncratic, the result of personal access to information. Magnets have been the subject of only limited, systematic study in their own right. In part, this reflects their relative scarcity; until recently there were not many magnets to study. In part, it reflects the contemporary culture: there was little interest in magnets because they were schools that ran against the grain.

Fortunately the research hiatus is over. Policy makers are no longer reduced to anecdote and myth, common sense and prejudice, a combination designed to frustrate informed decision making.

There is an emerging body of evidence about non-selective magnet schools, and it is of substantial interest.

THE EVIDENCE

The preceding narrative has sketched in the history and underlying philosophy of magnet schools, but having described magnet schools in a general way, what is it we know about them? With what degree of confidence may we make assertions?[10]

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[10] The U.S. Department of Education Office of Program Evaluation funded a major study of magnet schools which began in October 1981. The prime contractor is James H. Lowry & Associates of Washington, D.C. The subcontractor is Abt Associates of Cambridge, Massachusetts (USOE Contract No. 300-81-0420).

It is the first comprehensive study of magnet schools in the nation and incorporates both ESAA magnets and non-ESAA magnets. Much of the material in this report is drawn form *Survey of Magnet Schools, Interim Report*, September 30, 1982, the only published document to date, and extensive oral briefings and preliminary material in draft form received over the past year and one-half.

Phase I of the study was completed in September 1982. It included design research and data collection activities in six pilot districts.

Phase II is nearly completed, and the final report is scheduled for release in September 1983. The preliminary findings were presented to the project advisory panel for their review and comment June 2, 1983, in Washington, D.C. The findings were based on site work in fifteen school districts in five regions (Northeast, Southeast, Midwest, Southeast, and West). The total number of magnet schools in the fifteen districts is 190. Districts were selected with a wide variety of enrollments. Smallest was a Midwest district of six thousand students. Largest was a West Coast district of 115,000 students.

The preliminary findings, which will not change (except for stress of emphasis), are reported from oral briefings and preliminary working documents which are not yet available for formal citation. They are now in the hands of readers and the Advisory Panel, a group of "experts on public education, desegregation, and magnet schools from across the country" who have "guided the study staff toward addressing the right questions. . ." The panel membership includes:

Dr. Beatriz Arias
Professor
School of Education
Stanford University

Dr. Mary E. Busch
Member, Indianapolis Board of School
Commissioners
and
Director of Community Services
Indiana Central University

Dr. Emeral A. Crosby
Principal
Northern High School
Detroit Public Schools

Mr. Denis P. Doyle
Director of Education Policy Studies
American Enterprise Institute for Public Policy
Research

Dr. Robert Green
Dean
College of Urban Development
Michigan State University

Dr. Dennis R. Lubeck
Teacher
University City High School
University City, Missouri

Mr. Dan W. Alerenda
Deputy Director
National School Volunteer Program, Inc.

Dr. Charles V. Willie
Professor of Education and Urban Studies
Harvard Graduate School of Education
Harvard University

220

First, there are the numbers and a preliminary typology. The best and probably most accurate count of magnet schools indicates that in 1981-82 there were 1,018 magnet schools in the nation. The breakdown is as follows:

	ESAA-funded		*All Magnets*	
Magnet Grade Level	No.	%	No.	%
Elementary	158	62	601	59
Middle/Junior	39	14	173	17
Senior High	62	24	244	24
TOTAL	**259**	**100%**	**1018**	**100%**

Magnet typologies are not well developed because the phenomenon is relatively new, and the subject has not been the object of sustained research. The few that do exist are obvious: academically selective or non-selective (or selective by audition or other appropriate device). As is clear from the table above they may also be distributed by grade level, and source of funding. (ESAA refers to Emergency School Assistance Act; see appendix.) In addition, they may be arranged by theme. To date the following themes have been identified: Basic Skills, Fundamental, Bilingual, Montessori, Vocational or Career, Arts, Music, Performing Arts, Science, Mathematics (or both), Humanities or Social Sciences, Health Careers, Academic, Business, and Computer. Clearly, the only limit on thematic organization is the human imagination.

As we have suggested, research in this field is new but the preliminary findings are striking. The most important research is being conducted by James H. Lowry and Associates and their subcontractor; the Abt Corporation, uner the terms of a U.S. Department of Education Contract. The principal researchers are Rolf Blank of Lowry, Robert Dentler of Abt, and Catherine Baltzell of Abt.

The findings reveal what theory would predict about magnet schools: higher levels of teacher and student motivation, higher achievement, success with racial integration, significantly reduced behavior problems, greater teacher satisfaction, reasonable costs, and the like. The most welcome finding is that magnet schools are neither divisive nor elitist. Indeed, this may be the single most important finding, because the single strongest criticism of magnet schools is that they are elitist.

Before elaborating on this theme, it is useful to briefly but systematically sketch in the most important findings:

- Magnets produce education quality by virtue of three basic changes from traditional public schools:

  —a coordinated program based on an education "theme,"

  —improved student motivation,

  —specialized and highly committed staff.

- Although education quality differs among magnet schools, at the top of the range magnets achieve better academically, have better attendance, and exhibit fewer behavior problems.
- Most magnets are racially and ethnically integrated and reflect the larger population they serve. This effect is so striking and pervasive that it permits magnet schools to direct their energies to questions of education excellence, satisfied that their racial-ethnic balance is appropriate.
- Desegreation occurs voluntarily as parents and students identify special education programs that appeal to them. Thematic organization works.

THE FUTURE

Are the successes of magnet schools explained exclusively by the concentration of bright youngsters, or, in the jargon of social science, are there "school effects"? Are the schools doing something right, or is it simply the case that no one could turn these students off? The question is hardly trivial, given the problems the rest of American education faces.[11]

Are there program characteristics in magnet schools, as distinct from the characteristics of the students? There are, and not surprisingly they are characteristics one would expect: an orderly and humane learning environment in which much is expected of students and teachers; homework is required; absenteeism is not permitted, nor is vandalism, truancy, and general incivility; the students enjoy the respect of the faculty and the favor is returned. The principal, along English lines, is the headmaster, not an autocrat; indeed, in many magnet schools he or she still teaches on occasion, a symbolically important activity. Perhaps the single most important program dimension is intangible; students are expected to meet their responsibilities to the school and to themselves. There is the recognition that learning is by and large hard work: some of it is fun—having learned, for example, is more fun than learning—but for the most part learning requires diligence and enterprise. It is not a game, and students in magnet schools are put under real pressure to perform.

The opportunity for the school to apply such pressure is related to one aspect of selective schools that is so obvious observers frequently lose sight of it: students are not just selected "in", they are there beacause they want to be. They're volunteers.

Pride and satisfaction spring from geniune accomplishment, and the students in successful magnet schools are being held up to real standards. A well-executed biology experiment can't be faked; nor can a ballet solo. Advanced Placement (AP) math is a no-nonsense course, as is AP English.

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[11] For a more complete statement of the recent "school effects work" see particularly Barbara Lerner, "American Education: How Are We Doing?", *The Public Interest*, no. 69, Fall 1982, Denis P. Doyle in *Teaching Political Science*, forthcoming, review of *High School Achievement: Public, Catholic, and Private Schools Compared*, James Coleman, *et al*. Andrew Greeley, *Catholic High Schools and Minority Students*, (New Brunswick, N.J.:Transactions Books, 1982), and Michael Ruter *et al*, *Fifteen Thousand Hours: Secondary Schools and Their Effects on Children* (Cambridge, Mass: Harvard University Press, 1979).

Are there any lessons in this for the nation at large, particularly as it wrestles with the legacy of education failure?

The most important lesson is the most obvious: motivation no less than intelligence is randomly distributed in the population. Every major city and region in the nation could support staff, and operate magnet schools. Indeed, in those cities without magnet schools, the only option available to parents who care about quality education is to buy it, either in the form of private school tuitions or a house in the suburbs.[12]

Another option available to school systems is to do what New York City's new chancellor, Anthony Alvarado, did when he was regional superintendent of Spanish Harlem. He faced a unique problem—a disaster, some thought—and turned in into an opportunity. The Benjamin Franklin School, at 116th Street and the East River Drive, had fallen into academic and administrative bankruptcy: the school was a total loss. It was closed, cleaned up, and reopened as a new school, one without parallel in urban America. It was turned into an open-enrollment science-math school and will offer classes for kindergarteners to seniors in high school. Alvarado found an answer to academically selective schools. What of the kids that don't pass the entry examinations to selective schools but went to the trouble to take them? By definition they are motivated and eager; as well, many are as well qualified as those who pass the examination. No academic examination is sensitive enough or reliable enough to give anyone confidence in photo finishes. The lead Alvarado offered as Regional Superintendent could be followed across the country.

Recent research by a wide variety of researchers in this county and abroad confirms what most parents, teachers, and students already know: the crucial ingredient in school success is the school "ethos." This is a handy umbrella term designed to capture the sense of purpose of reciprocal expectation schools and their communities have for each other. When principals, teachers, students, and families have a clear sense of what their purposes are, they know what is expected of them. And they can deliver. The real power of selective schools is the same as the new non-selective science-math school in Spanish Harlem; it is their capacity to create a community of scholarship and shared interest, based as much on student motivation as high intelligence.

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[12] The Gallup organization has been conducting annual polls of attitudes toward public education for thirteen years; the results appear in the September issue of the *Phi Delta Kappan* each fall. The first ten are reprinted in book form, *The Gallup Pols of Attitudes Toward Education, 1969-1978*, Phi Delta Kappa, Bloomington, Indiana.

A standard question asked each year is, "What grade would you give the public schools . . . A,B,C,D, or Fail?" Commencing on this question, David Breneman of the Brookings Institution observed that "over time, the surveys report a steady drop in public regard for the schools. In 1974, 18 percent of those surveyed gave the schools a rating of A; by 1978 this figure had dropped to 9 percent. At the other end of the scale, 11 percent gave the schools a D or Fail rating in 1974, while 19 percent did so in 1978. Elaborating on the 1978 survey, the authors note that; "Attitudes are far more favorable in the smaller cities and towns than in the larger cities. In fact, residents of the central cities gave their schools the lowest rating in the nation . . . Of all groups, blacks living in the North give their public schools the lowest rating.'" See Joseph A Pechman, ed., *Setting National Priorities: Agenda for the 80s* (Washington, D.C.: The Brookings Institution, 1980), p. 209.

- Effective magnet schools provide quality education to average as well as above average students. Indeed, they do more for averages than above average students.
- The key characteristic of successful magnet schools is strong support from the Superintendent and School Board. This in turn is almost always related to strong community support.
- The evidence indicates that effective magnet schools have measurably better race relations.
- Magnet schools cost little or no more than regular schools to run, but freqently have high, one-time, start-up costs.
- Magnet schools frequently have strong linkages to other community resources—universities, business, hospitals, theaters, and the like. Thematic organization increases the likelihood of fruitful collaboration.
- Magnet schools are frequently much smaller than regular schools. While the research findings in this area are not conclusive, one hypothesis certainly warrants serious study: Many regular schools may have reached the point of significant diseconomies of scale.
- The location of magnet schools is unimportant: they succeed equally in "good" and "bad" neighborhoods, so long as they deliver on their promises.
- Transportation to magnet schools can be expensive and cumbersome. Insofar as it is, it becomes a proxy for community and student commitment.
- Magnet schools, properly organized, can be a powerful tool for desegregation, so powerful that schools may quickly turn their attention to education. They are a tool of tremendous strategic utility.
- The creation, organization, and management of magnet schools is widely understood and well within the administrative capabilities of most school districts.
- Magnet schools reflect a community's unique resources and capabilities, as well as needs.

In a more general vein, several other observations are in order. First, magnet schools change student and teacher behavior and attitude. Commitment is the key, and in this respect magnet schools begin to look like independent schools.

Second, the voluntary association of students and teachers produces powerful education dynamics. Even in non-selective magnet schools the ordinary student—by voluntarily enrolling—is committed to extra effort. The willingness to work translates into more work of higher quality. In the jargon of social research, there is a "black box" effect. The school makes a difference.

There is "value added." The student learns more than he or she would otherwise.

It also legitimizes school demands. It permits the school to ask for more, of both students and their families. At the same time, it frees teachers to act professionally. No longer concerned with school discipline, the teacher can concentrate on the subject at hand. Equally important, the student is a willing accomplice in the process. A sense of reciprocity is established.

Both the empirical evidence and anecdotes suggest one curious feature about the magnet school movement, both historically and in modern times. For reasons that remain obscure, there appears to be a naturally occurring upper limit to the number of magnet schools that a single school district will support.

In some cases, the school board simply refuses to let the number increase, even if there is fairly significant parental demand (that is, oversubscribed, wait-listed schools). The reasons appear not to be clever marketing: it is not designed to keep people clamoring for magnets. Rather, the existing culture of school organization and management seems unwilling and unable to expand beyond a finite number of magnet schools. Although Houston may be moving in this direction, there is as yet no district which has adopted a strategy of one-hundred percent magnet schools. The largest number to date is Buffalo, New York, in which thirty-seven percent of the schools are magnets.

Our long history of compulsory attendance and neighborhood assignment of students has led us to believe they are eternal verities, as if they have some educational or social significance and meaning. They have neither. Both were historical accidents that bear almost no relationship to any legitimate pedagogical objective. It is worth repeating that neighborhood assignment of students grew organically out of nineteenth-century commission sense. When a small school district built its second school it was to serve a swelling population, and its third and forth the same. What had been simple administrative convenience became a great American virtue. Compounded by the problems of race and the prospect of desegregation, neighborhood schools became an article of faith. But they clearly make neither administrative nor pedagogical sense today.

The wide diversity among magnet school themes makes the point in a powerful way: there is no one best school for everyone. Just as some students do well at a music and art magnet, others do well at an academic magnet. As a people, we do need some common core of shared, cultural literacy, but that can be achieved in different settings by different methods. There are different ways of approaching and appropriating the common culture: different is not bad, it is just what it suggests—different. And that is surely the reality of the modern American city: different people, with different interests and different learning styles. And different teaching styles, one might add.

The last is important because it brings us full circle to the question of school's effects. Do they make a difference, or is the secret simply smart kids? At one level, the question is utterly bizarre. Does anyone really think that schools don't make a difference? Students don't master AP Calculus by osmosis: they do so because the course is offered, because they work at it. And so it goes with ballet, the French novel, English literature, and reading. These are precisely the things that schools do: street wise kids may learn to run numbers, but they don't learn differential equations on the corner. Indeed, for street wise kids the school is the street, the numbers boss the teacher.

The answers to the Educational Excellence report and the other reports being produced are in: there are schools that meet their obligations to their students; there are students who meet their obligations to themselves and their schools. Magnet schools are delivering: they should be a source of inspiration to the rest of the nation.

CONCLUSION

Magnet schools are not a panacea, any more than comprehensive schools were. They are, however, a powerful tool for education change. They can and do meet the objectives set for them, including twin measures of higher standards and greater integration. In the early 1980s, such results can only be described as remarkable. They offer a hopeful sign of great promise. They work in large part because they embody two ingredients necessary to the educational process: choice and commitment. Based on the fact that schools have effects, they are designed to maximize the effects of strategic variables.

It is not surprising that high standards, commitment, hard work, and the flexibility to counsel students in and out of a magnet program should produce improved learning, high morale, and sense of community in a particular school. There is now sufficient evidence to support the establishment of such special schools to educate students committed to study and preparation in the fields of science and mathematics.

The more difficult question, and that for which we have little evidence available, is what potential the creation of selective schools or non-selective magnet schools may have for the improvement of math/science education system-wide. Although (to our knowledge) no systematic study has addressed this question directly, the following lessons may be gleaned from what we do know about existing magnet schools and about change in education.

First, individual schools represent the appropriate locus for change in education. Magnet schools—selective and non-selective—are built on the manipulation of key variables in the education process: student body, curriculum, faculty, leadership. Some school system problems can be more realistically addressed by creating islands of excellence in manageable units than by attempting broad, system-wide changes. When multiplied, they have the promise of building to a critical mass.

Second, magnet schools in science and mathematics can serve as laboratory schools for the development of curricula, teacher inservice, piloting materials, and developing instructional strategies for dissemination to the wider system. In order for this to happen, however, special attention must be paid to development of linkages to other schools. New ways for sharing resources and linking faculties have to be created. The connections will not occur automatically; they must be developed and implemented.

Third, the story of magnet schools—historical and contemporary—focuses on the important role external influences have played in their development. Most prominently, universities and industry have been significantly involved in the planning, design and implementation of magnet schools. One example of that role will illustrate the specific importance of such collaboration. The Houston Independent School District (HISD) science/math magnet schools program was motivated by the Chathem Report of the early 1970s. Published by CEOs of major corporations, it identified two key problems: one, an insufficient number of engineers overall, and two, the low representation of women and minorities in both practice and training. Out of this was born the Minorities in Engineering Program with operations on the national, regional, and state levels. Regionally, the Gulf Coast Action Committee for Minorities in Engineering has sponsored a corporate adopt-a-school project at the junior high school level to motivate students and prepare them for more demanding work in math and science.

Recognizing the need to begin preparation as early as possible, HISD has five elementary level magnet schools which focus on math and science. Admission is by interest; students need not demonstrate extraordinary aptitudes. The centerpiece, however, in the HISD science/math magnet program is the High School for Engineering Professions. The school opened in 1975 after one year of planning in close collaboration with both the higher education and the business communities. The curriculum guidelines were established by the deans of engineering schools; industry provided both equipment and personnel in the initial start-up phase and continues to provide such support on an annual basis. The school provides an annual report to its industrial partners. The report provides information on how the resources were distributed and what is happening to the students. The reports to date are, to say the least, impressive. As of 1981, one hundred percent of its graduates have gone to college—including the top-ranking institutions for engineering such as MIT, RPI, Rice, Cornell, and Princeton Universities.

The example of the Houston magnet schools is important because it illustrates the significant, substantive role industry and higher education can play in improving the relevance and quality of public school education and at the same time improve equality of access. Magnet schools, viewed as a strategy for the achievement of excellence and equity, suggest a federal role of some consequence.

Liberals and conservatives alike are persuaded that the nation's public schools are in distress; as well, they are persuaded that some modest federal role in education is desirable and appropriate.

The magnet school story suggests two things—one, an elaboration on existing activities, and two, a new program altogether. First, what we now know about magnet schools—beyond anecdote and story—is a product of federally funded research. The importance of this cannot be overemphasized. No other unit of government has the financial or organizational capacity—or incentive—to conduct research of national scope with national implications.

Too often, policy is made on the basis of opinion, only casually informed by fact. And while social research will never have the precision and focus of that of the natural sciences, thoughtful analysis with a solid evidentiary base improves the decision-making process. So it is with magnet schools. More research remains to be done; similarly there is a development and demonstration task, just as there is a dissemination task. There is a continuing role for the federal government to play in this area.

Second, the federal government could also play a significant role in helping localities think through magnet school design and implementation questions: to do so requires a combination of federal money and local interest. A straightforward program of federal matching grants for planning and implementation could be designed, providing support for a finite number of communities.

For example, a program deliberately modeled on one major American success story could be designed today at low cost, low risk, and with the high probability of substantial payoff. That would be a federally funded magnet school demonstration program building on the tradition of the Land Grant Colleges.

The strength of the land grant model is more than the establishment of a set of schools; it is in its ability to lay the groundwork for an intricate system of applied research facilities or laboratories for science-math education, and of training institutions for teachers and curriculum developers with demonstration and dissemination capabilities reaching down to the local level throughout the nation. The land grant model is fundamentally a decentralized system, with funding and control shared among the Federal government, the states, and the private sector. Its effectiveness for improving science and mathematics education is in its ability to combine research capabilities with education, demonstration, and innovation, and to drawn on the appropriate levels of government, private sector, and universities for maximum effectiveness.

The land grant agricultural research and dissemination model created a population of innovative American farmers receptive to change rather than fearful of it. Meeting the needs of the cadre of America's teachers and students for scientific and technical education presents a parallel set of challenges and opportunities.

Federal seed money at a critical juncture point could be catalytic. The preliminary cost information emerging from the Lowry study of magnet schools indicates that federal grants on the order of one hundred thousand dollars per school provide enough in the way of marginal resources to successfully undertake the necessary preplanning, planning and implementation to get a magnet school underway. Clearly this amount is not enough to do more than leverage local resources, but that is precisely the right strategy to employ in the creation of a reform program which requires local "ownership" to succeed.

At such a modest level of individual building funding, it is possible to conceive of a national program with great reach. Because magnet schools are particularly well suited to urban areas, the most promising way to begin would be to provide funding for three magnet schools in each Standard Metropolitan Statistical Area. Three magnet schools in each area would permit the community to simultaneously launch several thematic schools. The obvious first candidates would be a math-science magnet school, a humanities magnet school and an art-performing arts magnet school. The final decision should, however, be left to the individual community, which is the only level of organization which has a clear sense of the opportunities and problems unique to it.

Politically, such an approach should have broad appeal, reaching the majority of the nation's congressional districts and a substantial majority of the nation's population. In 1980, for example, there were 318 SMSAs with a total population of 169 million people, 74.6% of the nation's population of 227 million. Because of logistical and transportation problems day magnet schools are not well suited to rural areas, but a program for one or several magnet boarding schools, modeled on the North Carolina School of Science and Mathematics, could be included. To take this possibility into account, funds for each state to explore non-metropolitan magnet schools could be made available on a formula basis.

One of the most appealing aspects of such a program is the opportunity inherent in it to avoid old and acrimonious disputes about school boundaries and zones of attendance. Magnet schools designed to serve SMSAs or even larger regions would by their nature cross old boundaries, and should involve the various school districts and local governments in the magnet school's service area.

From the standpoint of the federal government, a magnet school demonstration program of this type would be time limited: it would not involve long-term operational funding, but would provide the critical resource mass to permit local authorities to initiate programs that would serve their own best interests, but for which they have no resources.

With more than two decades of federally funded research behind us, there is one thing we now know with some confidence. Reform and change can be stimulated by federal programs, but they will not "take" unless they are appropriated by the local community. The business of schooling goes on in the classroom and school building. It is part of a mysterious interaction of teacher and taught, the school and its community. But that process can be strengthened by a thoughtful and carefully crafted federal role.

The class of the year 2001 was born this year, and as we look to the twenty-first century we are struck by a remarkable spectacle: unless we initiate major changes today, we will perpetuate an education system designed for the covered wagon in the space age. Magnet schools offer a strategy of low-cost, high-visibility, incremental change that can transform American education.

APPENDIX

The Emergency School Aid Act (ESAA). Title VI of the Elementary and Secondary Education Act, became law in June of 1972. The legislation was to provide financial assistance "(1) to meet the special needs incident to the elimination of minority group segregation and discrimination among student and faculty in elementary and secondary schools; (2) to encourage the voluntary elimination, reduction, or prevention of minority group isolation in elementary and secondary schools with substantial proportions of minority group students; and (3) to aid children in overcoming the educational disadvantages of minority group isolation." (P.L. 92–318, Sec. 702(b)).

The legislation was based on the assumption, since shown to be true, that minority segregation in the schools is associated with educational disadvantages.[1] The ESAA was an attempt to encourage the elimination of these disadvantages through desegregation plans. The Educational Amendments of 1978 deleted the third purpose of the original ESAA from the legislation. (P.L. 95–561).

Following the 1978 Amendments, the ESAA program consisted of six subprograms. Five were nationally competitive programs, and one was a state apportionment program. The nationally competitive subprograms were special project awards (including Emergency Special Project out-of-cycle awards), Magnet School grants, Nonprofit Organization grants, Educational Television and Radio contracts, and Evaluation (of ESAA programs) contracts. The Basic Grants program was the state apportionment component of the ESAA.

All of the above programs were designed to aid school districts, financially, implementing or developing voluntary or required desegregation plans. Applications for ESAA funds were made directly to the Department of Education in Washington, and the Office of Civil Rights determined whether a desegregation plan was eligible for funding.

The Basic Grants component was the largest subprogram of the ESAA. In FY 1981 53% of the 515 applicants for Basic Grants were funded a total of $92,369,000. This made up 63% of the total ESAA funding for that year. These funds were allocated to states according to a formula which compared the ratio of minority to majority school-aged children among the applicants to those of other states.

Any state which was implementing or developing a required or non-required desegregation plan was eligible to receive funding through the Basic Grants program. In addition, all applicants for ESAA funding had to assure the federal government that they were not reducing local support of public education below that of previous years, and that they were currently spending as much per pupil from local sources as they had in the past. Basic Grant monies could be used for any activity which helped the Local Education Agency (LEA) meet the educational needs of an eligible desegregation plan.

In terms of funding, the second largest subprogram was magnet schools. To be eligible for ESAA funding, magnet schools had to have a special curriculum which was designed to attract students of varied racial backgrounds. In FY 1981, 64% of the 107 applicants for magnet school funds received a total of $30,000,000. This was 20% of the ESAA funding for that year. In the same year special projects grants made up 12% of the ESAA budget and nonprofit organization, educational television and radio, and evaluation contracts received 4%, 2%, and less than 1% of the total ESAA budget, respectively.

The nationally competitive programs had the same eligibility standards and application process as the Basic Grants program. However, the applicants were ranked nationally instead of within each state.

In August of 1981, the ESAA was repealed. The final year of funding under the ESAA was the 1981–82 school year. At the same time the ESAA was repealed, Chapter 2 of the Education Consolidation and Improvement Act was enacted. Funds are now available under these programs for use by LEAs requiring financial assistance in developing and implementing desegregation plans.[2]

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[1] Couson, John E., *et al*, *The First Year of Emergency School Aid Act (ESAA) Implementation*. Santa Monica, California: System Development Corporation, September 15, 1975, p. xi.

[2] Ferrara, Lynett, *et al*, *Emergency School Aid Act (ESAA): A Federal Program to Meet Desegreation Related Needs*, Draft; Washington, D.C.: Decision Resources, August 1982, p. xiii.
The Educational Amendments

9

AN ASSESSMENT OF PROGRAMS THAT FACILITATE INCREASED ACCESS AND ACHIEVEMENT OF FEMALES AND MINORITIES IN K–12 MATHEMATICS AND SCIENCE EDUCATION

Report from the Office of Opportunities in Science, American Association for the Advancement of Science (AAAS)

Prepared by Shirley M. Malcom, ***AAAS***

EXECUTIVE SUMMARY

Special programs in science and mathematics for minorities and females came out of the civil rights movements for these groups and out of a recognition of their severe underrepresentation in such careers. Thus, most of the intervention programs were aimed at producing American Indian, Black, Mexican American, Puerto Rican and/or women scientists and engineers. The response from government, universities, industry and the professions was to create efforts outside these institutions. Seldom were the institutions themselves changed to include these groups. The programs began mainly as locally driven initiatives, based on locally identified needs and dependent, for the most part, on locally derived resources. Only later did such efforts gain national attention or attract Federal or foundation dollars. The timing of this movement to move minorities and women into science and engineering careers was in some ways unfortunate, coming as it did after the major national effort to improve science education had wound down and as budgets for support of such initiatives were declining.

Intervention programs for minorities and women long ago implemented the idea of consortium-type arrangements among business/industry, university, government, and schools. They long ago involved teachers in training and in extracurricular activities for students, in strongly unionized as well as in non-unionized districts. They showed that students can, when given the proper tools, compete favorably despite previous disadvantages, and that equity and excellence are compatible goals.

The primary feature of successful programs for minorities and females seems to be that they involve the students in the "doing" of science and mathematics and convey a sense of their utility. This would be equally true for "career" driven" and science literacy focused programs.

Exemplary programs are sensitive to the group(s) they are intended to serve and address these audiences' fundamental needs for academic enrichment and career information. They also tie into the long range needs and goals of the target group. Exemplary programs for minorities recognize the deficiencies in performance many students are likely to have and stress rigorous academic preparation in mathematics, science and communications. Computers are a growing aspect of these projects as well. Students are carefully selected and grouped in ways so that they enjoy early success. Program participants are given the opportunity to work in teams on projects. Student research provides an excellent opportunity for students to develop and use multiple skills, integrating the knowledge they have already gained and stimulating them to independent effort.

Projects for females focus heavily on career awareness—on the utility of mathematics and science to whatever they might want to do. Young women are encouraged to take the courses available to them in high school. They are shown models of science and engineering professionals and students who "are making it" in these fields. The research base for women and mathematics programs was closely connected to intervention efforts. The same was not true for most minority projects. There is still a lack of fundamental research about mathematics and science learning by these populations and about the programs intended to address this.

Although programs often start outside of the school system, they usually end up inside. Because of the crucial role which the teacher plays, she or he must be "enabled to enable" the students under her or his guidance. Efforts are made to sensitize teachers to their own classroom practices which might have a negative effect on minority and female students. Project directors find it to be important to provide teachers with information on the types of teaching methods most effective with minority and female students in addition to helping them increase subject area competence. They also are given specific information on the careers in which one uses the science or mathematics.

Although they vary greatly in nature, longevity, base of operation, sources of support, goals and quality, intervention programs have demonstrated that there are no inherent barriers to the successful participation of minorities and women in science or mathematics. The evidence gathered to date indicates that if minorities and women are provided early, excellent and sustained instruction in these academic areas (all other factors being equal), then their achievement levels parallel those of white males. Additionally, the program models developed in these efforts have shown themselves to be effective in delivering quality education to all students.

Other findings of the study include the following:

- Unless programs "for all" specifically assess the status of, articulate goals for and directly target educational access problems of females and minorities (and also disabled youth), they are unlikely to be effective with these populations.
- The magnitude and complexity of the problem requires a large and continuing effort that specifically targets large sectors of our society—minorities and women—that are educationally "at-risk".
- Mainstreaming the concerns of these groups is possible and desirable, but only after specific targeting, followed by institutionalization of program elements critical to achievement of minorities and females, and monitoring to assure that participation levels are maintained.

- Successful intervention programs are those that have strong leadership, highly trained and highly committed teachers, parent support and involvement, clearly defined goals, adequate resources, follow up, and evaluation. For the positive effects to be sustained, these programs must eventually be institutionalized, that is, made part of the educational system.
- Scientists and engineers from the affected group must be involved in the planning as well as in the implementation of projects.
- Although "careers" have been the driving force behind most of the special programming in science, mathematics and engineering education for minorities and females, there is good reason to believe that literacy can also serve as the focus for intervention.
- Intervention programs must begin early and must be long-term in nature; "one-time" or short-term efforts do have a place for motivational, informational, supplemental, or trainsitional purposes.
- Research on cognition needs to be pursued in order to determine the most effective teaching styles for various groups of students. Research has shown some differences in male and female learning styles. Very little study has been done on language minorities or the effects of cultural differences on learning styles.
- Teachers are the key in providing quality and equity in science and mathematics education, and programs for their training and retraining should reflect both these concerns. Some persons expressed doubt that the shortage of qualified mathematics and science teachers was shared equally by all school systems and called for data collection that could determine this for urban, suburban and rural schools.
- Parents must be involved in programs targeted for minority, female and disabled youth. Their potentially positive impact on their children's decision making with regard to courses and careers cannot be overstated.
- Many programs previously supported by the National Science Foundation (both targeted and non-targeted efforts, such as Resource Centers for Science and Engineering and Student Science Training Programs) contained elements supportive of the movement of minorities and young women toward science and mathematics.
- More support is needed for dissemination of information about successful programs or replication of effective models.
- The current system of education in the sciences and mathematics has failed minority, female and disabled students as well as a large number of white males. More work needs to be done to test methods shown effective with minority, female and handicapped students on other student populations poorly educated in or motivated to science and mathematics.

10

A CASE STUDY OF LYONS TOWNSHIP HIGH SCHOOL (Summary)

Lorraine Borman, ***Northwestern University*** **and Peter Lykos,** ***Illinois Institute of Technology***

PREFACE

This report is a summary of a case study prepared for the National Science Board Commission on Precollege Education in Mathematics, Science and Technology. The topic is the Computer Literacy Program at Lyons Township High School (LTHS) in LaGrange, Illinois—a project designed to provide an environment in which the entire teaching staff and the total student body would have access to computing technology, and would be trained in "computer literacy."

In 1978, HumRRO, the Human Resources Research Organization, prepared a book describing instructional computing at ten precollege educational institutions. Those case studies were "written for administrators, teachers, staff and students who wish to plan, extend or improve the uses of computers for learning and teaching at their own schools."* The National Science Foundation suggested that our report might follow the "style" of the HumRRO book. We found that the story of LTHS was essentially the story of a plan, rather than a report of a completed project; it required more than the summary type of information that had been used in the HumRRO book. Therefore, we have produced two reports: first, the comprehensive report of LTHS and the Computer Literacy Project, and second, this profile report.

We studied LTHS over a period of 13 months, from the early teacher training workshops through the end of the first year of student literacy training, and into the planning stages for the second year. Our information is based on personal visits with the administrative and teaching staff at LTHS, on numerous phone conversations, on casual conversations with students, both in and outside the classrooms, and on the few published descriptions of the LTHS project.

This report of the computer literacy program at Lyons Township High School could not have been written without the wholehearted cooperation of the staff at LTHS. Superintendent John Bristol and Director of Curriculum and Instruction Estella Gahala not only met with us several times, but also arranged for us to talk with many of the teaching staff and to observe in the classroom. Julie McGee, Director of the Computer Literacy Program, was our guide to the program, describing what went on and why, and answering our endless questions—time after time after time. Susan Crain, Administrative Assistant to Estella Gahala, promptly provided us with requested LTHS documents, even during an office-moving period when it appeared that everything was crated, cartoned, and "not to be found"! We thank them all.

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EXECUTIVE SUMMARY

Introduction

Microcomputers have gone to school. At least 48% of the school districts in the United States now have one or more computers.[1] With approximately 60,000–100,000 computers in schools already (and projections say the number will be at least 300,000 by 1985), this averages though, to only one computer for every 660 students.[2] Educators are concerned about the use of computers and are asking how they can be carefully integrated into the existing school curriculum and by whom. At the same time, scientists and public policy makers have also expressed concern about the condition of education in this country. Most people believe that computers can help, but how?

Many schools have initiated innovative, but small-scale or prototype, programs for computer-based instruction and "computer literacy." However, one school district, supported by a farsighted Superintendent and a strong and financially secure Board of Education, proposed and implemented a plan to attain computer literacy for 90–100% of all students and teachers. This is a report of that work.

At Lyons Township High School in LaGrange, Illinois, a large-scale intensive program has been launched. Known as the Computer Literacy Program, the project is attempting "to provide training for all staff and students in the use of the computer, its functions in society, and its promise as an educational tool."[3] This report describes that activity from its inception in October 1980, through the end of its first operational year, August 1982.

The LTHS Computer Literacy Plan

In July of 1980, John Bristol was appointed Superintendent of the Lyons Township High School and arrived on campus the following September. During earlier discussions with the Board of Education, the question of computer literacy had come up. Bristol and the Board agreed that LTHS should develop a comprehensive approach to computer literacy for all faculty and students.

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[1] J. Goor, A. Melmed and E. Farris, Student Use of Computers in Schools, Fall 1980. A Survey of Public School Districts. FRSS Report No. 12, prepared for the National Center for Education Statistics, by Westat, Inc.

[2] Goor *et al.*, p. 12.

[3] Estella Gahala, Computer Literacy—A Comprehensive Program at Lyons Township High School, undated report (probably January 1982).

Bristol believed that in order to meet the educational needs of students, a plan to identify the major aspects of an appropriate school curriculum in computing was needed. He specified three areas:

LITERACY:	*All* students need to become familiar with the computer, how it operates, and how to use it in a variety of decision-making activities.
COMPETENCY:	*Many* students need the opportunity to develop substantial competencies in using the computer in their areas of interest, such as Physics, Mathematics or Accounting.
SPECIALTY:	A *few* students may need experience in focusing on the computer as an area of specialty, with the computer, versus an application, becoming the primary focus of instruction.[4]

The decision at LTHS was to focus initially on the literacy question since it related to the needs of the entire student body. The long-range plan, though, was a sequential procedure to finally develop a complete program for all students.

The LTHS plan was based on the following assumptions:

—That the computer is relevant to every discipline in the high school curriculum.

—That microcomputers had reached such a degree of reliability, cost-effectiveness and ease of use in local networking mode that hardware support of a hands-on large-scale introduction of computers into the high school was not a major issue.

—That the classroom teacher was the key to the appropriate development and implementation of computer education for students. However, most teachers were not qualified to teach computing or to apply it to their subject specialty.

—That the high school curriculum was already overcrowded with course electives. The objective of achieving computer literacy for at least 90% of the LTHS graduates was not likely to be met by adding a course on computer literacy.

—That there was no comprehensive collection of software sufficient to meet the objectives desired by the LTHS Board of Education nor did the LTHS teachers have the knowledge and expertise to make informed choices from the available curriculum software.

—That definitive research and development regarding how and where in the high school curriculum computer-enhanced curricular materials could be incorporated had not yet been done.

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[4] John Bristol, Personal Memo to PL, October 1981.

—That direct interaction with the computer—"hands-on experience"—is essential.

Consideration of these assumptions led to the conclusion that computer literacy should be "infused" into the school day, that sufficient machines for hands-on experience must be available, and that the existing teacher staff must be trained to carry out the computer literacy instruction.[5] Between October 1980 and March/April 1981, the following action plan was developed:

—To purchase 200 microcomputers, to equip eight labs, (four at each campus).

—To offer an in-service training program for all teachers.

—To invite the faculty to submit proposals. Each successful applicant would receive summer support (and programmer support) to develop a computer-based "packet" that might be used in one or more of the courses he or she would teach in 1981–82.

In-Service Training

The initial introduction to the computer was given in October 1980. A lecture on "Educational Applications of Microcomputers" was presented.

Between November 1980 and January 1981, a committee was formed with representatives from various departments who had some knowledge and/or interest in computers. On January 23, 1981, this committee organized an in-service program that included presentations by members of the LTHS staff and teachers from neighboring districts and demonstrations of hardware and software on most of the popular microcomputers.

During the period May 11–22, 1981, an eight hour in-service training program (broken into four 2-hour sessions) was offered to all staff members. Two hundred fifty-nine of the 264 person teaching staff attended the in-service training, along with 13 other staff members. However, the general impression one gets of this training program was negative. Most of the teachers interviewed felt that the program did not address their needs. The emphasis was on programming in BASIC. Afterwards, at the initiation of several teachers, the Superintendent was counseled to offer a redesigned teacher workshop with the emphasis on how to use existing programs, together with a computer "orientation" component. That was done, and that same cadre of teachers became the nucleus of the software development staff.

Software Development Workshops: Summer 1981

The 1981 "workshops" were conceived as a method of working toward two objectives: additional familiarity for the teachers and generating software for the first year of the classroom instructional program. This plan probably is one of the more controversial aspects of the entire LTHS computer literacy program.

The plan was begun after the in-service training in May 1981. Teachers were asked to submit proposals to develop software in collaboration with competent programmers. Faculty from 12 of the 13 departments comprising LTHS submitted proposals. This represented active involvement by 47 teachers, some of whom worked together authoring projects. By the beginning of the academic year 1981–82, 56 packets had been "mostly" completed.

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[5] Gahala, p. 2.

Programs were primarily of the drill and practice variety, on topics ranging from spelling, genetics, recipe adjustment and playing the guitar. Each completed packet included documentation which contained suggested teaching activities.

Computer Literacy Week Training for Teachers

It was originally intended for the content of the teacher literacy workshop (May 1981) to be the content of the student literacy program. However, the teachers felt that the literacy package should allow students to use programs without having to be programmers. A computer literacy package was then designed and developed by four teachers. It combined the use of films, lectures and hands-on introduction to microcomputers. The four teacher-authors presented a leadership training workshop on January 23, 1982 to 25 invited teachers. That group then worked with the balance of the faculty at another half-day workshop held January 29th.

Beginning a week later, these same teachers taught the computer literacy package to their students, and, it appears, with a reasonable degree of confidence. This training seems to have been well received and successful.

The Student Computer Literacy Package

The first major activity which affected all students was Computer Literacy Week, begun in February 1982. The literacy package, written by the teachers, and taught to all of the teachers in January, was now ready for the students. The literacy package was a series of four classes, two in the classroom, and two in the computer lab using lectures, films and hands-on experience to achieve the goal of "providing both students and teachers with a computer experience that makes them feel more comfortable about the computer as a part of their lives."[6]

The *Teacher's Guide* states: "When students have completed the unit, they should be able to:

1. Identify the major components of the computer;
2. Understand the basic operation of a computer system;
3. Identify and use some terminology associated with computers;
4. Locate and use the keys on the TRS-80 keyboard;
5. Understand how a simple program operates;
6. Recognize how computers are used in different fields;
7. Identify major advantages and disadvantages in the use of computers."

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[6] "Teacher's Guide for a Micro-Course in Computer Literacy," undated (probably 1982) 59+ pages.

Thirty-six hundred fifty-eight students were scheduled into the Computer Literacy Week program, 95% of the total student population. In 1982–83, the computer literacy package will be taught only to incoming freshmen and transfer students, probably in mid-September.

Summary

The LTHS project is probably the largest and most comprehensive introduction of computer technology into the secondary school environment in the U. S. and possibly worldwide. It was done very rapidly. A massive infusion of microcomputers was made at LTHS over a very short period of time. The teachers became the focus for bringing computer enhancements to the curriculum. The full weight of the administrative structure was brought to bear on the process—from the superintendent to the departmental chairs.

The teacher training activity, after one and one-half years, has resulted in approximately 50 teachers who can be considered either computer-trained or computer-motivated. The balance of the teaching staff has had 20 hours of in-service training and were able to effectively teach students a minimal computer literacy package.

Although the initial thrust of the LTHS plan was "computer literacy" for teachers and students, this massive introduction of computer technology into a school of 3800 students and 270 teachers has also had, and will continue to have, an increasing effect upon computer science education itself and in the use of the computer as a problem solving tool in appropriate subject areas.

The basic literacy package is now an integral part of the LTHS academic program. Some courseware has been developed and is being used by some classes—albeit not on a large scale. Computer competency, as in problem solving in mathematics and in the sciences, is at a modest level and growing slowly. Computer specialization courses (programming) are growing rapidly.

For students, the computer literacy package can only be considered an introduction, but combined with using computers appropriately in their classes, LTHS students will be familiar with computers and understand how they can be used in many areas of life—thus achieving most of the goals of the program.

For the administration, the entire process has brought forth a number of important issues, especially in future teacher training and courseware evaluation and selection.

The LTHS computer literacy program has shown that the high school is the right place to introduce computing education, that low cost personal computers have made this the right time for the introduction of widespread computer literacy, and that teacher training, motivation and support is the right way to introduce computers into the schools. Now, the challenge is: How to effectively apply the technology that has been so effectively introduced into LTHS.

PROFILE

SIZE and STAFF	Lyons Township is a comprehensive four year high school serving 3850 students in west suburban Chicago.

	The faculty of 274 teachers is highly trained; 83% have advanced degrees.
STUDENTS	The student population is 95% white, 2% black, 1% Spanish-speaking, 2% other. In 1980–81, there were eight National Merit finalists, 158 Illinois State Scholars; 84% of students who took Advanced Placement tests received placement and credit at the college level.
CURRENT ISSUES	The Board of Education, in cooperation with the Superintendent, the Curriculum Committee and the faculty, have initiated a plan to achieve 90–100% teacher and student computer literacy. District enrollment is declining at a rate of 5% per year.

HISTORY OF INSTRUCTIONAL COMPUTING

1967	Offered first course in computer programming using administrative computer services equipment—an NCR Century 200 system.
1977	Purchased two Wang computers for Mathematics Department. Offered *Introduction to Computers,* using the BASIC language, as part of freshman algebra. Batch processing of student jobs.
1979	Purchased two TRS-80 microcomputers for use by the Science Department and another Wang computer for programming instruction.
1980–81	Purchased a Burroughs B1955 computer for administrative and instructional computing support. Offered programming classes in RPG, COBOL and FORTRAN in the Business Education and Mathematics Departments with four terminals for student use. Computer Literacy plan for teachers and students approved. Purchased 200 TRS-80, Model III microcomputers. In-service training for teachers: BASIC language programming and general computer literacy. 96% of teaching staff attended.
1981–82	3658 students scheduled into four session computer literacy short course. January, 1982, all instructional computing moved to microcomputers. Total microcomputers in school, 236.

ORGANIZATION AND MANAGEMENT OF ACADEMIC COMPUTING

MANAGEMENT	All computing instruction is under the Director of Curriculum and Instruction.
COMMITTEES	The Curriculum Council, composed of the department chairperson, assistant principals, principals, Director of Curriculum and Instruction, and the Superintendent, are studying the curriculum phase of the instructional computing program. Teacher generated proposals for curriculum alterations are presented, debated, approved or rejected by this group.
INCENTIVES	Faculty in-service computer training has been provided for the past one and one-half years. All teachers have completed 20 hours of training. Faculty were funded for two summers to develop computer-based instructional materials. Forty-eight teachers received compensation for this work in 1981, 39 in 1982. Teacher Development Centers are being designed that will provide both computer hardware and software for experimental and training purposes and that will offer consulting and training assistance for teachers desiring to implement computer-based materials in their classes. Part-time programming assistance will be available. Teachers are encouraged to attend professional association meetings and present papers describing the LTHS Computer Literacy Program. Stipends are provided for the advisors of the high school computer club.

STUDENT ACCESS TO COMPUTING

One goal of the instructional computing program at LTHS is to provide computer literacy to 90–100% of the students. A second goal is to offer computer-based instruction in all 13 departments of the school. A third goal is to offer "computer science" instruction—programming courses and problem-solving methodology.

During 1981–82, the first year of the computer literacy program, possibly 20–25 classes, out of a total 290 offered, had some instructional computer experience. This was in addition to seven programming classes in the Mathematics and Business Education Departments. In addition, all students had a four period (200 minutes) short course on computer literacy.

COMPUTERS	236 Radio Shack TRS-80, Model IIIs
	Three Wang microcomputers used primarily for demonstration purposes.
	Ratio of computers to students is 16:1.
USERS	3650 students, January-June 1982, four 50-minute sessions, Computer Literacy Package.
	Potential Access (assuming 20% utilization of microcomputer lab facilities): All classes could have computer-enhanced hands-on instruction at least eight classroom periods per semester. Thus, a student theoretically could be in three or four computer-enhanced classes, totaling 24–32 classroom sessions per semester. These estimates are based on one student per computer during each computer lab session.
	In 1981–82, computer labs were used 20.6% of the available time. Computer lab sessions were scheduled by all academic departments of the school.
WHERE	Microcomputers are located in the two LTHS buildings. There are eight computer classrooms, with configurations ranging from 13 disk-based machines to 50 networked machines.
	Word processing and programming classes share labs with disk-based systems.
	Computer labs are open for student use after school hours.

COSTS AND BUDGETING

FUNDING	100% local District funding for instructional computing.
COSTS	
1967–1980	Instructional costs were included with administrative computing services.
1980–1981	$197,819[1]
1981–1982	$183,119[2]
1982–1983	$50,000[3]

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[1] Hardware $97,819; Teacher Training & Software Development $100,000.

[2] Hardware $159,119; Maintenance $4000; Software Development $20,000.

[3] Budgeted for hardware and maintenance.

Figures include hardware and maintenance for Radio Shack TRS-80 microcomputer support of instructional computing. Also included, for 1980–81, are expenditures for in-service teacher training, hiring of substitute teachers, and costs of production of in-house software. Costs for 1981–82 include summer teacher workshops for software development. Because of the first year decision not to acquire outside software, there are no substantial software purchases.

The costs of the departmental computers are not included. Also not included are software purchased by individual departments for use on the TRS-80s. Electricity charges, estimated at $6900/year for 236 microcomputers, and supplies such as diskettes and printer paper, estimated at $2000/year minimum, are also not included.

COMPUTER LITERACY

FOR: Total student population 1981–1982.

BY: Regular teaching staff.

SINCE: January, 1982.

PROGRAM: *Computer Literacy Week.* Lectures and audio-visual: uses and applications of the computer. Introduction of basic terminology. Impact of computer on society and career choices in computing. Hands-on experience: introduction to computer keyboard, parts of the computer, and observation of interaction between programming statements and subsequent operations and responses.

Computer-enhanced instruction begun in 1982 for many classes.

COMPUTER SCIENCE

FOR: Students in grades 9–12 (Freshmen only in upper 2/3rds of class rank).

BY: Mathematics and Business Education Departments.

SINCE: 1967

Program revised in 1981–1982. Since January, 1982, all programming courses use microcomputers.

PROGRAM

Business Education Department
Introduction to Computing (BASIC)
Business Computer Programming 1 (BASIC)
Business Computer Programming 2, 3 (COBOL)

Mathematics Department
Computer Mathematics (FORTRAN)
Computer Problem Solving (BASIC)
Introduction to FORTRAN

Independent Study and "contracts" are also offered.

Registration in these seven courses increased by 46% in 1981–1982.

Total registrants for 1982–83: 587, 16% of the total student population.

OUTREACH

EXPERTISE

The computer literacy package was taught by LTHS staff to 330 teachers from township feeder schools and to 200 parents under the auspices of the Home-School Council.

LTHS has hosted over 213 visitors from 84 institutions worldwide. A report, "Computer Literacy—A Comprehensive Program at Lyons Township High School," was written in response to questions from these visitors.

LTHS teachers speak at many conferences and workshops.

FACILITIES

LTHS Summer School during 1982 offered "Introduction to Computers."

"Introduction to Word Processing" was offered for the first time by the Adult Education Center at LT.

MATERIALS

Teacher designed and developed programs are being worked on. At this time, they are not being disseminated.

LESSONS LEARNED

The 1981–82 year was one of transition for instructional computing at LTHS. The introduction of 236 computers into the school system and the move towards computer literacy for 90–100% of the teachers and students meant a period of trial, and sometimes error.

At the end of the first year of the computer literacy program, the Director of Instruction and Curriculum, Estella Gahala, made the following observations:

1. Computers are an instructional tool of equal applicability across disciplines.
2. Broad faculty participation is essential . . . (but) critical decisions must be made by those who are knowledgeable and ultimately responsible for program outcomes.
3. Major factors for success are Board of Education and administrative commitment.
4. The peer teaching plan for staff development and training is effective for building in-house expertise. (See References 1 and 3.)
5. Separation of computer literacy, computer curriculum, and computer science is essential in assuring development of the program.
6. Broad accessibility to computers is an appropriate high priority in the program.

Other observations were made by Julie McGee, Project Director for Computer Curriculum Development:

1. Faculty training efforts should emphasize *use* of the computer in the classroom, not programming.
2. Effectiveness of a program is strongly dependent on the attitude of the teacher.

PLANS AND GOALS

COMPUTER SCIENCE	A study has been initiated to examine the scope and sequence of computer science/data processing courses.
EQUIPMENT	Redeployment of computer hardware is being completed to equip two Learning Resource Centers, two Curriculum Development Centers, and two word processing labs for student use.
SOFTWARE	Integration of CAI into the total curriculum is envisioned. Examination of materials available and desirable is necessary.

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11

BUSINESS' ROLE IN PRECOLLEGIATE EDUCATION: A SURVEY OF IMPACTS AND ATTITUDES (PRELIMINARY REPORT)

Report from The Conference Board, Inc.
Prepared by Leonard Lund and E. Patrick McGuire, *The Conference Board*

INTRODUCTION

The basic raw material for all business operations is people. To the extent that business firms are able to hire adequately trained young people, they are thus capable of replenishing the basic feedstock for continued successful business operations. Whether or not a supply of trained or trainable workers remains available is a matter of deep concern to business managers and influences many policy decisions, e.g., hiring and promotion standards—and even helps to determine where to locate new business establishments.*

Because the majority of the persons 18-24 hired by business are high school graduates, business is vitally concerned with the kind of training provided during their precollege or secondary education. Business increasingly focuses on the quality of precollege education and, in particular, the extent to which the nation's secondary schools are preparing students to work in a business environment becoming ever more technical.

The Conference Board and the Commission on Precollege Education in Mathematics, Science and Technology of the National Science Board have jointly sponsored an inquiry among business executives to determine their experience with, attitude toward and aspirations for secondary schools. This survey was conducted through two separate questionnaries distributed to approximately 2000 executives during the summer of 1983. One questionnaire was sent to public affairs officers of 1000 major companies to elicit information on company attitudes toward and involvement with local public school systems. A separately designed second questionnaire was sent to a list of 1000 training and personnel officers to get their evaluation on the capability of newly hired high school graduates and to ascertain the effects upon company hiring policies. They were also asked about company involvement with local schools.

This report is based upon responses from 514 executive—324 public affairs officers, 190 training or personnel officers. It provides the statistical support and verification for oft-quoted comments about the inadequate preparation for functioning in the world-of-work given to young people in most local school systems. The report also confirms the depth of corporate concern about "educational failure" and enumerates the ways in which businesses face the need for reversing current trends in educational excellence.

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* Leonard Lund, *Factors In Locational Decisions*, The Conference Board, Information Bulletin No. 66, 1979, pp. 7-8.

THE EDUCATIONAL QUALIFICATIONS OF NEWLY HIRED HIGH SCHOOL GRADUATES

In recent months, a number of prestigious groups, among them The National Commission on Excellence in Education, the Task Force on Education for Economic Growth, and the Business-Higher Education Forum, have issued reports calling attention to the linkage between education and economic and technological progress. All of the reports stressed the urgency for remedying educational insufficiencies as being vital to the nation's interest and future. All of these reports recommended, among other steps, increased involvement by business through partnerships, or other cooperative mechanisms, as requisites in any program of educational uplift.

The Conference Board survey underscores these same points. Most of the responding executives pointed to the inadequately prepared high school graduates in the local labor pool (particularly for technical jobs) and concluded that their firms should do more to improve the quality of education in the secondary schools. Giving their perception of corporate educational priorities, more than 80 percent of the public affairs officers noted their company's concerns with the quality of courses in math, science and technical studies available in the local schools, while almost 65 percent had similar concerns for the quality of coursework in reading and language skills. The availability of vocational education was of lesser concern.

Specifically, three out of four respondents identified the quality of teaching as the single most critical operational issue. About half of the respondents were also concerned with scholastic standards, a third with the administration of schools, and about 30 percent with school financing.

The human resources executives surveyed, those responsible for hiring and training, present much the same conclusions. While most of of them find the new hires adequate in all but writing skills, very few of them judge the newly hired high school graduates to be good in any of the key subject areas.

TABLE 1

PREPAREDNESS RATING OF NEWLY HIRED HIGH SCHOOL GRADUATES

Subject	*Rating by Respondents*		
	Good	*Adequate*	*Poor*
Reading/Comprehension	14.8%	65.9%	19.2%
Writing/Communication	6.6%	42.0%	51.4%
Mathematics	6.7%	61.5%	31.8%
Science	7.9%	57.6%	34.4%
Computer Skills	6.8%	46.6%	46.6%

On the other hand, when asked also to assess the current trend—whether the proficiency in these subjects by new hires was improving or declining—77 percent of the same respondents reported improvements only in computer skills; while 65 percent reported declining abilities in reading, 74 percent in writing, and around 60 percent in both science and mathematics.

As for company experiences over the past few years in finding high school graduates to fill jobs that require a proficiency in science or math, fewer than 9 percent of them have had access to an "adequate" supply of well-prepared candidates. Almost half of the respondents (49%) say that they have an adequate supply of marginally-prepared young people, while the remaining 7.7 percent have found only limited numbers of the latter.

As depressing as the above results may seem, these judgments apply only to those young people who have met the minimal requirements for being hired. The remainder of the labor pool, therefore, might well be even less adequately prepared, and would reflect the comment made by an executive of a Chicago bank who said, "I used to be able to hire one out of three appliants for a job, but now I can see as many as twenty to find one adequately prepared."

THE IMPACT OF EDUCATION SHORTFALLS ON BUSINESS OPERATIONS

While there is general concern about the quality of the future work force, the lack of adequate preparation for work of current high school graduates has not been serious enough to affect most company operations. About one out of five companies report that shortages exist which affect their operations. A like percentage of the responding companies found that they must provide some remedial training in science and mathematics. A smaller percentage indicate that they have had to lower hiring standards.

In two industry categories, banking and utilities, the need for more employees with adequate training in math and science has resulted in higher percentages than the other industries having shortages of adequately trained people which affect company operations. Almost 40 percent of the responding banks, and 25 percent of the utilities were so affected. These industries also had to provide extra training because of the requirements of the jobs filled by young people, and in the utilities, the concern for safety.

A quick review of current trends indicates that even industries that can now meet their workforce needs of technically-literate young people from the present crop of high school graduates, will find it more difficult to do so in the near future. A recital of those trends begins with the finding of this survey that there is serious concern over the declining quality of secondary education in job-related subjects, and includes these facts as well:

> School enrollments in elementary and secondary schools declined 13% nationally from 1971 to 1981, and occurred in 42 states.
>
> Test results of international competitions indicate increasingly poor showing of U.S. students in mathematics and science.

> Shortages of teachers qualified to teach mathematics, science, and technological subjects are serious and growing.
>
> The growing technological complexity of many oncoming jobs will require a more skilled workforce.

Today, the search for solutions to these critical issues has become almost a national crusade involving participants from government, business, labor, education and all other ranks of society. The aforementioned studies sponsored respectively by the U.S. Department of Education, and the Education Commission of the States, stress the need for greater discipline and more demanding challenges for students. These recommendations are not unlike the attitudes expressed by the surveyed business people. Executives believe not enough emphasis is being placed on the basic education courses—such as language, reading, math and science. Some managers believe, for example, that students have too much free time, too little instruction, and that course loads and achievement goals should be increased in order to attain higher educational standards.

Corporate executives are also concerned, to a lesser degree, with the efficiency and administration of the secondary school system. They recognize, as well, that significant changes in the way public education is financed may be necessary in order to provide the talent and resources needed for better teaching performance.

IMPROVED TEACHING OF MATHEMATICS, SCIENCE AND TECHNICAL SUBJECTS

As noted above, executives believe that more time must be spent on basic job related subjects, among them science, mathematics and computer literacy. Improving the quality of teaching in these subjects is the single most important task, in the view of 80 percent of surveyed executives.

More than 80 percent believe that business involvement can have a major impact on the improvement of secondary education, science and mathematics in particular.

RELATIONSHIPS WITH MATHEMATICS AND SCIENCE FACULTIES

Approximately 48 percent of the firms studied say that their managerial personnel have had some regular contact with science and mathematics teachers in their local school districts. Among those who have had such contacts, and would rate their competence, approximately 27 percent rated the teachers as good and 22 percent rated them average. Less than 5 percent evaluated them as excellent, and 2 percent said they were poor. The largest segment, almost 45 percent, said they could not determine their competence.

Contact with science and math faculties comes primarily through company personnel and/or human resources executives, organizational development specialists and science and technology personnel.

EXACERBATING THE TEACHER SHORTAGE SITUATION

While acknowledging that shortfalls in math and science education at the precollegiate level exist primarily because of a shortage of competent and dedicated teachers, companies also admit to the fact that they have aggravated this situation by hiring away math and science teachers for engineering and science positions in industry. Approximately a third of the firms studied admit to such practices. However, many of those questioned point out that it would be impossible for them to discriminate against the employment of such specialists, simply on the basis that such job applicants had previously been teachers. The key, a majority of executives believe, is to raise the salaries of math and science teachers to a level where such positions are competitive with the entry-level jobs for new scientists and engineers in the private sector. Thus, such a "brain drain" from the educational community may not take place.

WHAT HAS BUSINESS DONE TO HELP?

Businesses have always had a relationship with the schools in their locality. This relationship, however, is being restructured in many ways so that it has begun to have greater importance for both parties.

Traditional relationships were based upon general acceptance of the public school system as the source of the company's work force, and the understanding among the local youth that when they graduated from high school they would seek employment in one of the local businesses. These beliefs, underscored by a continuing relationship between personnel administrators in business and career counselors in the schools, led to such programming as cooperative education, summer job programs, Business-Education Days and Career Days.

In recent years, the span of contacts were broadened in most localities as community relations activities grew and became an integral part of company public affairs. It became commonplace for school representatives and corporate officers to meet at community meetings where the agenda dealt with issues that were only tangentially education-related. The result of many of these increased opportunities for interaction has been a closer relationship and an expanded interest by business in the local education system.

This, in part, accounts for some of the statistics on school involvement by major companies, most of which predate current concerns. These statistics indicate that two-out-of-three of the major corporations assist by providing equipment, study materials and loaned facilities to high schools in the community. The kinds of equipment contributed may depend upon the industry and may include audio-visual equipment, office machines, automotive equipment, and, increasingly, computers for classroom use.

Almost to the same extent, about 60 percent of the responding companies reported that their executives and employees were loaned to local schools to serve as classroom teachers, consultants and program developers. The same number of companies replied that they were involved in cooperative education programs and/or provided internships for students from the local schools. In most instances, internships in mathematics and the sciences are aimed at college students, or increasingly, at college-bound youth to give them support and encouragement to stay in these disciplines.

An adopt-a-school program, or a similar in-depth relationship and identification with a single school, engages almost 40 percent of the companies surveyed. This is probably the most thorough commitment a business can make to a school since it implies that whatever success or failure the relationship might produce would be a shared responsibility. This kind of program means a commitment by the business of substantial time, talent and money—in most cases, a real working partnership.

The visible or perceivable assistance has been considered more effective and important in trying to make major improvements in school functioning. However, there are companies that believe that business should not become involved with a particular school or with the day-to-day operation of learning within a particular school or with the day-to-day operation of learning institutions, this being the responsibility of the professional educators, so their assistance is aimed at helping them. This assistance is by the funding of new development efforts or innovative programming, underwriting the cost of specialized training for teachers, creating new or experimental materials and programs and any other uses that usually cannot be financed under the regular school budget.

Large numbers of businesses make financial contributions to schools, almost 55 percent of the surveyed companies said they did, but they find this to be less satisfactory than other kinds of involvement as a means of improving educational standards. These contributions are directed to assorted purposes. The most frequent is assistance to specific programs—most often for supporting athletic and cultural programs. Contributions for scholarships are mostly for college students or specialized summer programs (42 percent of the companies contribute) but only 27 percent of the companies specify that these be given for studies in mathematics, science or engineering. Many of the engineering scholarships are reserved for minority students as part of an organized effort to train more minority engineers.

As helpful as these contributions may be, only 27 percent of the companies felt that providing direct grants to schools was the effective way of improving secondary eduation. Instead, three out of four respondents favored active encouragement for higher education standards, advocacy of means to raise the level of teaching competence, and the continuation and expansion of programs of assistance now deemed effective in upgrading secondary education by more than half of the participants—supplying equipment and teaching materials and the loan of personnel to local high schools.

Companies also provide assistance by encouraging employees, at all levels, to volunteer for and participate in local school systems as school board members, consultants, and so forth. Three quarters of the companies studied say they actively encourage their employees to serve on voluntary or elective bodies used to administer school systems. Up to half of the firms believe that such employee participation has resulted in upgrading of the local school system.

Many of these companies permit this to be done on "company time" and a handful of companies provide financial support to the schools in which their employees are active as a further incentive. A major manufacturer that awards a stipend of several hundred dollars to any community organization in which an employee is active, doubles the amount for schools.

BUSINESS PLOTS FUTURE ACTIONS

Many of America's leading corporations, such as Exxon, IBM, and others have evidenced a long standing interest in and commitment to public education as a high priority public affairs issue. However, until recently this attention was not widely shared in the business community. While almost 80 percent of the surveyed companies held the opinion that the quality of public education could be affected by corporate advocacy, half that number, about 42 percent, had not as yet made education a primary agenda item in their public affairs program.

At the same time, 65 percent of the public affairs officers express the view that their company should do more to assist in improving the quality of public education. However, with the concentrated attention on the issue by major business organizations and "business roundtables" in California, Minnesota, New York and other states, the issue is moving rapidly to the top of the priority list for many more firms.

The "roundtables" are a relatively new phenomenon at the state level. They include top business firms organized to examine public policy issues and to make use of their combined weight to influence state policies. At the local level, much the same trend is becoming apparent. Almost 55 percent of the respondents reported that they have joined with other businesses, with business organizations or broader-ranged groups to assist in improving public education. This portends a higher level of activity by many more companies, since peer influence tends to work in the direction of the one in the group with the most missionary zeal.

TOP MANAGEMENT'S VIEW

Obviously, top management plays a pivotal role in whether or not a business organization actively participates in both advocacy and assistance functions designed to improve precollegiate education. The survey results show that slightly more than half of the senior executives are characterized by their public affairs executives as "concerned" with improving the quality of secondary education.

TABLE 2

INTEREST LEVEL OF TOP MANAGEMENT IN IMPROVING SECONDARY EDUCATION (PERCENT OF RESPONDENTS)

According to Public Affairs Executives	*Interest Level*	*According to Human Resources Executives*
17.9%	Concerned and personally involved	18.9%
25.9%	Concerned and wishes company to be involved	21.6%
12.7%	Concerned but primarily involved through trade organizations	12.6%
29.6%	Generally interested and wishes to be kept informed	22.6%
15.4%	Generally interested but only as it affects company operations	18.9%
2.7%	Shows no interest in the subject	7.4%

NOTE: Totals exceed 100% because some respondents indicated more than one choice.

More than three-fourths of those who are so concerned wish their companies to be involved and will assume some personal involvement for themselves. But a substantial group of chief executives are characterized as "generally interested and wish to be kept informed"—a somewhat lukewarm endorsement of the importance of this topic. Nonetheless, the senior public affairs executives, and the human resource and training executives as well, believe by a substantial majority, that their firms should do more to assist and improve the quality of precollegiate education—particularly in the areas of math and science. But there are limits to such support. When firms were asked why they could not do more—despite their philosophical support or improvements in precollegiate education—the overwhelming majority said that they were "doing all they could with the resources they have." A lesser number give the reason that "it is not a corporate responsibility" but even fewer can say that they just have no interest in the issue. The least frequent reason given by major companies was that "it is unlikely that we can have any impact." In general, educational improvement, and particularly in improving the quality of education in science and mathematics, in the opinion of public affairs officers, business can have a substantial impact (34.5%) or a moderate impact (48.9%). This impact can best be translated into achievement through a strong advocacy role by individual executives and business, along or in concert. Increasingly, all these are being enlisted in this current major public effort to improve public education.

A COLLECTION OF COMMENTS FROM RESPONDENTS

In addition to the completed survey instrument, many respondents included covering letters which provided explanations of their responses and additional details of programs and experiences. Others were called to clarify some responses and added information at that time. These comments were used to derive the following opinions, suggestions and recommendations that some of the business executives considered worthy of passing along.

Among the major areas of concern frequently expressed were the length of the school day for high school students and the availability of too many "junk" courses as electives. Many of the comments were directed to the fact that students would attend only in the morning and be seen "hanging around town" all afternoon. Other comments focused on the level of truancy and the "liberal" attitude toward non-attendance. Some conceded that cutbacks in school budgets might be partially the reason, and suggest that some programs staffed by volunteers might be undertaken.

The weakness in the required standards that permitted soft courses to be acceptable as credit toward graduation was blamed upon poorly prepared teachers and administrators, and upon the concept that "everyone can graduate." One or two of the respondents believed that administrators were more interested in "covering up" school conditions by maintaining high numbers of graduates as indicators of success. Many of the business people felt that higher state standards for graduation must be set and a tougher curriculum demanded, and a few suggested statewide testing before graduation.

On the teaching of science, mathematics and assorted technological subjects, including computer literacy, many resondents complained about the inadequate preparation of the teachers and the "turn-off" effect this shortfall had upon students. Some complained that study materials and equipment given to schools was not used for the same reason.

Asked to give their opinion on when science should begin to be taught, many commented that it should be part of the elementary school curriculum as one of the basic courses, but that it was introduced only in the upper grades. Several stated that some teachers would be happy to add science if they were not forced to stick to the 3 R's. One executive commented, "The stumbling block is the principal. In our town they are ex-Phys. Ed. teachers and science to them is a high school course. It's too hard for young kids." Most of the respondents suggested that a strong effort be made to educate the educators about the need for science and technology. Several said that business people should demand that the schools include such instruction, but others believe that they could only advise and offer cooperation and assistance.